08-02-00

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UTILITY PATENT APPLICATION TRANSMITTAL UNDER 37 CFR 1.53(b)	ATTORNEY DOCKET 80097JDL
To: Commissioner for Patents Box Patent Application Washington, D.C. 20231 EDGE ENHANCEMENT OF GRAY LEVEL IMAGES First Named Inventor (or Application Identifier): Yee S. Ng, et al	**Express Mail Label No.** **EK825657735US** **Date:** 8/1/00

JC862 U.S. PTO 09/629696 08/01/00

jc849 U.S. PTO 08/01/00

Enclosed are:

1. [X] Specification
2. [X] 29 Sheet(s) of drawing(s)
3. [ ] Information Disclosure Statement Under 37 CFR 1.97.
4. Combined Declaration for Patent Application and Power of Attorney:
   - 4a. [X] New
   - 4b. [ ] Copy from a prior application (37 CFR 1.63(d) (for continuation/divisional with Box 11 completed)
5. [ ] Incorporation by Reference (useable if Box 4b is Checked) The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. [X] Assignment of the invention to **NexPress Solutions LLC**
7. [ ] Certified copy of a priority
8. [ ] Associate Power of Attorney
9. [ ] Deletion of Inventor(s). Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

10. [ ] If a 111A application prior to examination of the above-identified application, amend the specification at Page 1, After the title, by inserting the following:
--CROSS REFERENCE TO RELATED APPLICATION
Reference is made to and priority claimed from U.S. Provisional Application Serial No. , Filed , entitled .

If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

11. [ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: ,

12. [X] Please address all written communications to Lawrence P. Kessler, Patent Department, NexPress Solutions, LLC, 1447 St. Paul Street, Rochester, NY 14653-7001.
Please Direct all telephone calls to James D. Leimbach at 716/253-0125.

The filing fee has been calculated as shown below:

FOR:	NO. FILED		NO. EXTRA	RATE	FEE
BASIC FEE					$ 690
TOTAL CLAIMS	24	- 20 =	4	x 18 =	$ 72
INDEPENDENT CLAIMS	4	- 3 =	1	x 78 =	$ 78
[ ] MULTIPLE DEPENDENT CLAIM PRESENTED				+ 260	$0
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[X] Please charge my NexPress Solutions LLC Deposit Account No. **50-1466** in the amount of **$ 840.**

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[X] The Commissioner is hereby authorized to charge any additional filing fees required under 37 CFR 1.16 or credit any overpayment to NexPress Solutions LLC Deposit Account No. **50-1466.**

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James D. Leimbach/alb
Telephone: 716/253-0125
Facsimile: 716/253-5525

Attorney for Applicants
Registration No. 34,374

ORIGINAL

Application Based on

Docket **80097JDL**
Inventors: Yee S. Ng and Hwai-Tzuu Tai

EDGE ENHANCEMENT OF GRAY LEVEL IMAGES

Commissioner for Patents,
ATTN: BOX PATENT APPLICATION
Washington, D. C. 20231

Express Mail Label No.: EK825657735US

Date: 8/1/00

09/755,955 01/05/01

EDGE ENHANCEMENT OF GRAY LEVEL IMAGES

Cross-Reference to Related Applications

This application is related to the following applications filed on even date herewith:

1. U.S. Patent Application Serial No. _____ filed in the names of Yee S. Ng et al, and entitled EDGE ENHANCEMENT PROCESSOR AND METHOD WITH ADJUSTABLE STRENGTH OF GRAY LEVEL OUTPUT.

2. U.S. Patent Application Serial No. _____ filed in the names of Yee S. Ng et al, and entitled EDGE ENHANCEMENT PROCESSOR AND METHOD WITH ADJUSTABLE THRESHOLD SETTING.

3. U.S. Patent Application Serial No. _____ filed in the names of Hwai-Tzuu Tai et al, and entitled IMAGE RECORDING APPARATUS AND METHOD PROVIDING PERSONALIZED COLOR ENHANCEMENT.

4. U.S. Patent Application Serial No. _____ filed in the names of Hwai-Tzuu Tai, and entitled GRAY LEVEL HALFTONE PROCESSING.

Background of the Invention

Field of the Invention

This invention relates in general to digital image processing and, more specifically, to a digital image processing system and method for enhancing the edge characteristics of printed or displayed images that are subject to a halftone screening operation. The processed image data may be reproduced on a display or printing system using gray level pixels that vary in size or density depending upon the medium.

Description Relative to the Prior Art

Multiple level halftones using gray level pixels are known to improve image quality of pictorial images for lower resolution printers. Different types of halftones are known to improve the stability of the (EP) electrophotographic process (such as full-dot or mixed-dot halftones, see in this regard "Gray Level Printing Method With Embedded Non-Uniformity Correction Method Using a

Multi-bit LED Printhead," IS&T 47 Annual Conference Proceeding, p. 622-625; 1994; and U.S. Patent No. 5,956,157, the contents of which are incorporated herein by reference thereto) or to improve on the reproduction of detail (such as partial-dot halftone). Image segmentation methods are known to distinguish between the input of local image types so that one can select different halftone types used for different local input image types (such as using a lower screen frequency mixed-mode halftone for pictures and interior of large text in order to improve the EP stability and reduce density contouring, and using a higher screen frequency partial-dot for finer fonts and edges to improve fine line reproduction). Blending of various multiple level halftones in the boundary regions of image types (using fuzzy logic type of approach) is also known to reduce abrupt transition artifacts between segmented image regions, see in this regard U.S. Patent Nos. 5,200,831; 5,694,224; and 5,956,157. A proper usage of the segmentation methods can produce good EP stability for large area images and produce fine line details, but it does not produce an anti-aliasing effect for near-saturated text and graphics. Anti-aliasing methods such as GRET (Gray Enhanced Anti-aliasing Technology) are known to produce enhanced anti-aliased text/graphics for input saturated text/graphics using multiple level rendering, see in this regard U.S. Patent Nos. 5,450,531; 5,600,761; and 6,021,256. However, GRET is not very effective to do anti-aliasing for non-saturated text. The inventors have recognized that it would be desirable that the above methods can be merged to produce an anti-aliasing effect for saturated as well as for non-saturated text (even with a multiple color system), to reduce effects from input scanner induced moire (such as input moire caused by high frequency features on images) and still maintain long-term stability of the color electrophotographic process.

Summary of the Invention

In accordance with a first aspect of the invention there is provided a method for processing gray level image data comprising subjecting the gray level image data to halftone screen processing to form halftone processed screen image data; analyzing a current pixel of the halftone processed screen image data to a

test criterion to determine if the current pixel is a possible saturated color text image; and if the current pixel meets the criterion for being a pixel of a possible saturated color text image providing a gray level image enhanced processing modification of the current pixel for output to a printer or display; and if the current pixel does not meet the test criterion for being a pixel of a possible saturated color text image providing the current pixel gray level as processed by the halftone screen processing for output to a printer or display.

In accordance with a second aspect of the invention there is provided a method for processing gray level image data comprising subjecting first gray level image data to plural separate halftone screen processings to form plural separate halftone processed screen gray level image data; analyzing a current pixel of the first gray level image data for contrast index; in response to the analyzing generating blending coefficients for processing that current pixel; processing the plural separate halftone screen processed image data with the blending coefficients to blend halftone screen processed gray level image data of the same current pixel to form a blended halftone screen processed gray level current pixel; comparing the gray level of the blended halftone screen processed current pixel relative to a threshold criterion; and if the gray level of the blended halftone screen processed current pixel meets the threshold criterion providing a gray level image enhanced processing modification of the blended halftone screen processed gray level current pixel for output to a printer or display; and if the gray level of the blended halftone screen processed current pixel does not meet the threshold criterion providing the current pixel gray level as processed by the blended halftone screen processing for output to a printer or display.

In accordance with a third aspect of the invention there is provided a method for processing gray level image data comprising: subjecting first gray level image data to plural separate halftone screen processings to form plural separate halftone screen processed gray level image data; blending halftone screen processed gray level image data of the same current pixel to form a blended halftone screen processed gray level value current pixel; and if the blended halftone screen processed gray level value current pixel is substantially a maximum density pixel or is adjusted to be a substantially maximum density pixel

subjecting the blended halftone screen processed gray level current pixel to a gray level image enhanced processing modification to reduce jaggedness in an image.

In accordance with a fourth aspect of the invention there is provided an apparatus for processing gray level image data comprising: first and second halftone screen processing devices that form plural separate halftone screen processed gray level image data; an input to each of said screen processing devices to input image data representing a current gray level pixel; a device for analyzing the current pixel for contrast index; a device responsive to the contrast index for generating blending coefficients; a blending operation processor that generates a blended halftone data output for the current pixel; an input at the blending operation processor for inputting respective outputs of the first and second halftone screen processing devices and the blending coefficients; a gray level image enhancement processing device connected to the output of the blending operation processor; a detector for examining the current pixel after operation by the blending processor and neighboring pixels thereof after operation of the blending processor and determining if the current pixel and such neighboring pixels represent a substantially binary image file and generating a signal relative to such determination; and a selector , responsive to the signal, that selects either the gray level image enhancement processing device output or a bypass representing a blended halftone data output.

The invention and its further objects and advantages will become more apparent after reading the detailed description of the preferred embodiments presented below.

Brief Description of the Drawings

In the detailed description of the preferred embodiments of the invention presented below, reference is made to the accompanying drawings in which:

FIG. 1 is a schematic block diagram of an image processing system according to the invention;

FIG. 2 is an illustration of a window of nine pixels and illustrates one exemplary approach to determining contrast index;

FIG. 3 is a view illustrating a determination of a blended rendered dot value using a graph depicting blending coefficients vs. contrast index for each of two different halftone processings;

FIG. 4 is a block diagram showing greater detail of a portion of the system of FIG. 1;

FIG. 5 is another block diagram showing greater detail of a portion of the system of FIG 1;

FIGS. 6 (a), (b) and (c) are illustrations of 19 x 19 pixel halftone screen tiles that may be used as one of the halftone screens in the system of FIG. 1;

FIGS. 7 (a), (b) and (c) and 8 are illustrative examples of screen address "bricks" and lookup table respectively that are used to generate halftone screen pixel rendered values for the pictorial screen of FIGS. 6 (a), (b) and (c);

FIG. 9 is a flow chart that may be used to determine a brick coordinated address in a lookup table structure of FIG. 8;

FIG. 10 is an example of a text screen tile for use in determining a halftone rendered text screen value;

FIG. 11 is an example of the screen address brick that is used to generate the halftone screen pixel rendered values for the text screen of FIG. 10;

FIG 12 is a block diagram of a preferred gray level edge enhanced processor used in the system of FIG 1;

FIG. 13 is a chart illustrating a relationship relative to different types of output from the gray level edge enhancement processor;

FIG. 14 illustrates schematically a binary image wherein 255 represents maximum density and zero represents background or no density;

FIG. 15 illustrates schematically a binary image that is provided with gray level edge enhancement in accordance with output from a medium strength setting for a lookup table;

FIG. 16 illustrates schematically a binary image that is provided with gray level edge enhancement in accordance with output from a low strength setting for a lookup table;

FIG. 17 illustrates schematically a binary image that is provided with gray level edge enhancement in accordance with output from a high-strength setting for a lookup table;

FIG. 18 is a graph showing a relationship of input pixel gray values to modified gray values in accordance with color saturation tweaking;

FIG. 19 is a block diagram of a printing or display system that incorporates the image processing system of FIG 1; and

FIGS. 20 (a) and (b) illustrate an example respectively of gray component replacement (GCR) and undercolor removal (UCR) in a color transformation process.

FIGS. 21-1 to 21-6 represent an illustration of steps for forming a brick structure;

FIG. 22 is a flow chart of a process for forming a brick structure;

FIGS. 23 (a)-(c) are illustrations of a tile structure and respective brick structures for a screen having 171 lines per inch at 0 degrees rotation angle; and

FIG. 24 is an illustration of a dot size driver having a circular or spiral type of growth pattern and used in generating rendered screen values for a tile.

Detailed Description of the Preferred Embodiments

The method described herein is intended for a full process color system that has multiple color separations, however the invention described is also applicable to black and white and accent color systems . There is herein described, for clarity purposes, a method and apparatus for processing image data for only one of the color separations of a plural process color separation image forming system. Extension to all color separations is an obvious matter such as by providing additional or parallel systems for each color or processing different colors serially. The input image to the system is assumed to be a continuous-tone color separation (post-RIP rasterized image) after GCR (Gray Component Replacement) and UCR (Under Color Removal) processings have already been applied. The input image data is gray level image data that may have been derived from scanning of a document by a scanner. In FIG. 1, there is shown a schematic of an image processing system according to the invention. A 1-D (one

dimensional) look-up table (LUT) 12 or global color process control (re-programmable) is used to operate on the input data so as to enable last-minute customer desired personalization or preference to affect the color separation coloring of the already rasterized image (such as redder, greener, etc.) during the real-time running of the printing system. The modified input data as output by the LUT 12 is then input to and analyzed by an adaptive screen analyzer unit 14 (image segmentation) to generate an image type identification function (in this case, contrast index). This contrast index acts as a pointer to obtain blending coefficients (BC 1, BC 2) for the halftone screens of choice. In this example, it is assumed that there are only two screens being used simultaneously (the text screen and a pictorial screen). It is understood that more intermediate screens can be used see in this regard U.S. patent No. 5,956,157 the contents of which are incorporated herein by reference . In this example contrast index is one known method of using the basic concept of image segmentation and fuzzy logic approach to assign the percentage of usage of certain screens of choice.

The modified input contone data is also passed to the two screener or LUTs 18, 20 for halftone processing at the same time. In each of the screener LUT blocks, it is assumed that the input contone data is halftoned by only that screener (such as a very high frequency soft screen for text) under the control of a screening address calculator 22 that has input from the pixel clock and line clock. A halftone rendered value is the output from each of the screening blocks 18, 20. In the case of rational screens, the repeating calculated address of the halftone blocks for the two screen choices are not necessarily the same. Then a blending operation is done in processor 24 that takes the blending coefficients and the halftone values of all the screens into consideration so a blended rendered halftone value (blended halftoned value) based on the result comes out. Since the edges of non-saturated text/graphics have a high likelihood to use mostly the high frequency soft pictorial screen (which employs a partial-dot the growth pattern) and while the interior of the larger text has a higher likelihood to use mostly the lower frequency (mixed-dot growth pattern) screen, fine details are preserved and the large area EP stability is achieved at the same time. Moreover, since the edges of non-saturated text are using higher frequency screens, it does not get degraded

by normal lower frequency screen processing (it is almost like an anti-aliasing effect is done for non-saturated text and graphics). The blending of screens also reduces the artifacts at the boundary of image types. This also reduces the moire problem caused by scanning input images that have high frequency features and output with a fixed screen (screen angle, screen frequency) halftone screens.

As noted in U.S. Patent No. 5,694,224 in gray level printing, each pixel has the capability to be rendered in several different dot sizes or densities, and thus different gray levels. The number of gray levels is at least three whereas in a binary system only two levels are possible, background and highest density. However instead of simply providing each pixel with an independent gray level, several pixels may be organized together to form a super pixel, or cell. Each of the pixels in a cell is then provided with a gray level. The human visual response integrates the various gray levels of the individual pixels in the cell to a single perceived gray level for the cell. This is similar to the basic concept of binary halftoning. The number of tone skills for a cell is increased greatly, however, due to the number of different gray levels available for each pixel. For example, instead of only the two levels provided in binary halftoning for each pixel, 256 levels (including zero) can be provided with gray level printing for each pixel in the cell. The formation of the dots in the pixels of the cell can be performed in a number of different manners to achieve different desired results. The dots can be formed as "full" dot, "partial" dot, "mixed" dot or fixed dot to provide gray level halftoning. The partial dot formation process and mixed dot formation process are described in the aforementioned U.S. Patent No. 5,694,224.

Up to this point, the system can produce an anti-aliasing effect for non-saturated text and reduce moire caused by beating of the output screen to an input, and at the same time maintain stability for the EP process. The system also needs to produce an anti-aliasing effect for saturated text. Further, for color systems, since GCR and UCR are often used; some of the originally saturated text (in monochrome) has been changed to near-saturated text. In order to resolve this problem, a programmable adjustable threshold/detector 26 is used on the blended halftoned data (see FIG. 1). Thus blended gray level halftone values beyond a certain threshold are each converted , by GRET adjustable threshold/detector 26,

into a binary 1 value and the rest are set to a binary 0 value before they are input to the GRET anti-aliasing detector 28. In this regard reference is made to U.S. Patent Nos. 5,450,531 and 5,600,761 the contents of which are incorporated herein by reference for disclosure of GRET processing although other gray level edge enhancement processors may be used for improving edges of saturated text. Anti-aliasing edge enhancement output suggestions from GRET set the pointers to an LUT that contains multiple level output values to smooth the edges. Different strength (gray values) LUTs can be provided for the purpose of providing more or less smoothing or line-width control as shown in FIG. 1. This particular GRET strength selection being made by an input to LUT 30. Of course, based on the GRET algorithm for multiple level images, the detector 26 would also determine whether there are other values than the binary (a high but not saturated value and/or a low value) that exists within the window of examination. If there are other gray values within that window, the bypass gray values (blended halftoned values as output by blending operation processor 24) will be used instead. In this regard it will be noted that the GRET adjustable threshold/detector 26 provides additionally a bypass of the GRET processor 28 of the output of the blending operation processor 24. In addition to the bypass data a selector signal is provided as an input to the GRET or bypass selection device 32 so that the selection device 32 can determine whether to pass the GRET processed data as modified by GRET strength selector 30 or the bypass data which represents the blended halftoned data output by blending operation processor 24. There is thus accomplished anti-aliasing for near-saturated text/graphics in addition to the improvement in quality for non-saturated text as well in the method and apparatus of the invention.

In FIG. 2 there is illustrated a method to calculate the contrast index (that is the method used by the adaptive screen analyzer 14). In this method a window of nine pixels (which is taken from the output of global color process control device 12) is used and the absolute value differences between certain neighboring pixels are examined to determine a maximum difference between a pair of neighboring pixels. In this regard reference may be made to U.S. Patent No. 5,956,157.

In FIG. 3, there is shown an example of how the blending coefficients (BC 1, BC 2) are calculated (100 percent equal 1) in a two screener fuzzy logic system with the contrast index. There is also indicated an example of how the blended halftone value (rendered value) is calculated from the blending coefficients and halftone dot gray values of different halftone screen look-up tables outputs.

The current system offers independent tuning of the multi-level outputs within the LUTs from the two halftone screens and the GRET LUT edge values. It is desirable to match the two halftone screens gray levels and screen structure. In this regard there is provided a match of density and structure at the boundary region between image types, so the gray values within the two screener LUTs are tuned to achieve this match namely, at a similar input value, the output densities (not necessarily the same gray output values, since the screens are different) of the two screens are selected to match well (of course the screen structures of the two screens are also selected to reduce texture mismatch), so that a gradual transition between image type regions can be accomplished. For a similar reason, the gray values and GRET LUTs (high/medium/low-the high, medium, low refers to different degrees of aggressiveness in terms of anti-aliasing) are tuned independently from the screener LUT values in order to give an optimized performance for near-saturated text anti-aliasing effect (depending upon customer choice). The current system described herein provides the independent means for all of that to be done.

Docket - 96-0-96-0-96-0

Preference Color Saturation Tweaking

A 1D (one dimensional) global color process control LUT 12 is used at the beginning to ensure the possibility of last-minute tuning of preference color even during the running of the printer after the images have already been RIPed (raster image processed). One input to LUT 12 is the 8 bit input data for the color separation image. The second input to LUT 12 is a color tweaking value for adjusting saturation of the color separation image. As shown in FIG. 18 there is provided a schematic illustrating the gray level input into LUT 12 and the corresponding gray level output from LUT 12 and the range of adjustments possible by modifying the color saturation on the output by the operator providing

a color tweaking adjustment input that is available at the control panel of the workstation WS in FIG. 19. It will be noted that this input comes after the job image buffer and is effectively modifying image data after the image data is output from the job image buffer. Thus experimentation may be done by the operator in making copies (such as proof copies) with various tweaking adjustments without rescanning of original hardcopy documents or rerasterizing of the image data when the data is presented in electronic form. Preference color tweaking provides the last step of minor color adjustment to allow a user to adjust color if the user doesn't like the color being printed as may be observed from a proof print. Thus a de-saturated color may be adjusted back to a more saturated color. There may be provided the boosting of a specific color in the image. The coloring is not intended to provide fine-tuning of each color to be color accurate or to match color as a known color management process may be provided in a front end portion of the machine prior to rasterization. For full color or process color processes (cyan, magenta, yellow and optionally black) color tweaking is preferably performed before halftone processing because there are improved results obtained by modifying the contone (continuous tone) data rather than the halftone processed data. An advantage of having adjustments be provided to the contone data is that modifications to a dot structure or dot data formed after a halftone process may introduce unwanted artifacts (interaction from other color channels) in the dot structure and tends to provide more color variations or at least tends to be more difficult to predict/control adjustment of color.

In order to handle some limited degree of GCR/UCR ranges, an adjustable GRET threshold step is also provided at threshold detector 26 for different degrees of near-saturated text and graphics anti-aliasing needs. Other enhancements include putting more than one of the pictorial screens within the screener 2 (screener 20) LUTs so different pictorial screens can be selected within one printed page without a need to reload the LUT (of course the screen address calculator's screen positioning increment calculation would need to be changed from one pictorial screen to the other). Further improvements include using more than two screens at a time in the blending operations for smoother transitions.

In FIG. 4, there is shown a detailed implementation of the functions such as the adaptive screen analyzer 14 (that generates the contrast index, please see FIG. 2 for its functional description), the blending coefficients LUT 16 (please see FIG. 3 for its functional description), and the detail of the blending operations block 24 (that utilizes the output values from the screeners and the blending coefficients as pointers to obtain an output value). In this case there is described a pre-calculated LUT approach (to obtain very high-speed operation) to generate the output (blended halftone data, please see FIG. 3 for the equations) to the GRET blocks (see FIG. 1 for detail). As may be seen in FIG. 3 after the contrast index is calculated the blending coefficients are generated according to the illustration in FIG. 3. For the example of a contrast index of 0.4 an output value from screener No. 1 (18) is multiplied by 70 percent while the output from screener No. 2 (20) is multiplied by 30 percent. As can be discerned from FIG. 3 contrast indices that are relatively small or relatively large have 100 percent multiplied by one screener value and 0 percent multiplied by another screener value.

In FIG. 5, there is shown a detailed implementation of the functions such as screen address calculator 22, screeners 18, 20 using LUTs (for high-speed operation) and the blending operation blocks 24 (blenders). To achieve higher speed, a dual processing channel approach is used. In this dual channel approach the current even pixel and the current odd pixel are separately simultaneously processed. In order to calculate contrast index of the current even pixel there is only required certain neighboring odd pixels of the current even pixel. For the current even pixel a first in first out buffer (FIFO) 21a is provided to store the neighboring odd pixels necessary for the contrast index determination for the current even pixel. Similarly, for the current odd pixel a FIFO 21b is provided to store the neighboring even pixels necessary for the contrast index determination for the current odd pixel. The current even pixels are input respectively to the even pixel screen LUTs 18a, 20a; and the current odd pixels are input respectively to the odd pixel screen LUTs 18b, 20b. The outputs of the screeners and the blending coefficients calculated from the respective contrast index for each of the odd and even pixels are input to the respective pixel blending operation processor 24a, 24b. For rational screens, coordinate addresses of rendered screen values

(depending on screen angles and screen frequency, different color separations can use different screener angles and frequencies, those addresses can be different) are generated in accordance with the description provided below. The pixel clock and line clock are used to increment counters depending upon the current pixel location with respect to the rational screens to obtain a coordinate output to the halftone screener LUTs (18a, 18 b, 20a, 20 b) that store the halftone screen multi-level output based on the input pixel value and coordinate value calculated.

Generation of Rendered Screen Values

With reference now to FIG. 6 (a), (b), (c) there is illustrated in each drawing a conventional screen tile defined within a 19 x 19 rectangular array. The screen tile is a 4 x 15 rotated square. The screen tile is used to render 154.6 LPI (lines per inch) screen rulings at 600 dpi (dots per inch) within 14.93 degrees screener angles. It will be understood that in each drawing the tile represents halftone rendering values for one gray value, 255, 128, 2 in an 8-bits per pixel system.

Reference will now made to the data in FIGS. 7(a), (b), (c) which illustrates for each of gray level planes 255, 128, and 2, a string of 241 numbers that can serve as a repeatable numerical series that represents the respective halftone tile. Although in FIG. 7(a) there are shown 241 numbers in various rows and columns, the 241 numbers are best visualized as being in a single row or brick of 241 numbers. For the case of planes 128 and 2 it is more apparent that in the typical gray level case the numbers in the brick are not all the same. As indicated in FIG. 7 (a), the brick width is 241, the brick height is 1, and there is an identification of a brick offset of 177, which will be described below. The use of the brick concept will be demonstrated to show that halftone rendering values may be determined for any pixel location in an image using the 241 values associated with each gray level. It will be understood of course that these 241 values are determined based on the screen ruling frequency, screen angle and size of screen tile and represent the halftone rendering values for only one color separation. Typically, it is desirable that each color separation have a screen angle different

from that of another color separation color when used to make the same multicolor image particularly with regard to pictorial halftone screens.

With reference now to FIG. 8 there is shown an illustration which is in furtherance of the explanation of the concept of the use of the brick series of numbers of rendering values. As shown in FIG. 8 a pixel value P(x,y) is input to an optional lookup table which is used in the situation where the incoming pixel is a different order (bit depth) from that of the rendering values. Thus, if the incoming pixel has a gray level bit depth of, for example, 12, it may be converted by the lookup table to a bit depth of 8. The pixel to be halftone rendered and modified so as to be of the appropriate bit depth is indicated as g(x,y). The gray level of this incoming pixel identifies or serves as a pointer to one of 256 brick planes 0-255. Each brick plane incorporates the series of numbers of the brick for that gray level. Thus, plane 255 incorporates the series of 241 numbers shown in FIG. 7 (a). In addition to the gray value of pixel g(x,y), there is also provided the x,y coordinate location or image pixel address for the pixel in the image. The coordinate location will be used to locate the specific rendering value for that pixel in the pixel plane defined by the gray level for that pixel.

Reference will now be made to the flowchart of FIG. 9 for calculation of a coordinate value I,J in a brick plane wherein there is known the current pixel's coordinate value in the x,y image plane. In the example provided the coordinate value J. is at all times equal to one since in this particular case the brick height is one because of the nature of the halftone screen lines. For other screens the brick height may be two or more.

In order to determine a rendering value for the pixel g(x,y) the gray level plane is determined by the gray value of the pixel and consider now the first line of pixels to be rendered. The coordinates in the image plane of the first pixel in the first line of pixels are X=0, Y=0. The first number in the brick (I=0,J=0) of the gray level plane of that pixel is the rendering value for this pixel. The second pixel in the first line of the image plane (X=1,Y=0) is rendered by the second number in the brick of the brick plane having the gray level for that second pixel and so on for the first line of pixels g(x,0) until the 242nd pixel is to the rendered. For this pixel we return to the beginning of the brick string or series of numbers

and repeat from brick coordinate I=0 to 240 in repeat fashion and so on until all pixels for line Y=0 are halftone rendered.

For the next pixel line Y=1 the first pixel in this line g(0,1) will map to offset location I=177 in the brick, which location is particular for this screen, and different lines of the image will be found to have the starting position in the brick begin at different calculated offset locations. The next pixel in the image line g(1,1) will map to rendering location I=178 and so on until location 240 is reached. Mapping of the next pixel in this image line then begins at rendering location I= 1. Thus, an offset is only used to start a new image line at various calculated offset locations. Thus, for pixels in the second image line, Y=1, the pattern is a mapping sequence of I=177 to 240 (for image pixels X=0 to 63), I=0 to 240 (for image pixels X=64 to 304), I=0 to 240 (for image pixels 305 to 545), etc. until all pixels in this line are halftone rendered. For the next following line Y=2 the repetition pattern is I=113 to 240, 0 to 240, 0 to 240, etc., until all pixels in this line are halftone rendered. It should be noted that for each pixel to be rendered a variable will be its gray level value so that a different brick plane is considered on a pixel by pixel basis depending upon the gray value of the pixel.

A robust implementation of this processing is indicated by the flowchart of FIG. 9 where the pixel having coordinates (x,y) is mapped to a certain location (I,J) in a brick plane which location is then provided as one input to a halftone screen lookup table that also has input to it the gray value g(x,y) of the pixel. The lookup table stores rendered pixel values for halftone rendering of the image pixel g(x,y). In this example there are 241 x 255 rendering values in the LUT (brick width times number of brick planes). Further reduction of the size of the table can be made by recognizing that gray value 0 and 255 have I and J values that are irrelevant since in this example each pixel having a gray value of 0 and 255 is rendered at that respective value. In the flowchart of FIG. 9 the pixel image coordinate value x,y is input to a calculator that takes the value of the x-coordinate and adds that to a value of the y coordinate which has been first divided by the brick height and then multiplied by a brick offset value. This sum is then divided by the brick width wherein only the remainder is retained as the brick coordinate value for I. For example, where X=178,Y=1,Bh=1,Bs=177,and Bw=241, the

calculation is made of adding 178 + (1/1)177=355, which is then divided by the brick width of 241 to yield a remainder I=114. The J coordinate value is determined by taking the y coordinate value in the image plane and dividing it by the brick height and retaining the remainder as the value for J. In this example for this screen the value of J is always zero, however, as noted above, some screens may have a brick height of two or more and so the J coordinate in the brick plane becomes essential to determine. Implementation of the brick coordinate calculator may be by software as processed by a computer or by a chip that is designed to perform this calculation. The calculation may be expressed by the formula:

$$I = (X + (Y/Bh) * Bs) \%Bw$$

wherein "%" indicates that a division operation is made wherein a remainder is determined. As noted above, Bh in certain situations is equal to one so the equation simplifies in such situation to:

$$I = (X + Y * Bs) \%Bw$$

As noted in FIG. 5 separate simultaneous processing may be made of the odd and even pixels and a hardware or software implementation may be provided to accommodate calculation of brick coordinate value simultaneously for the odd and even pixels. In addition, since there will be rendering with both a halftone pictorial screen and a halftone text screen, there may be simultaneous implementation of calculations of brick plane coordinates for the text screen as well as the pictorial screen. An example of a text screen is illustrated in FIG. 10 and a look up table featuring rendering values utilizing the planes of bricks technique for rendering pixels processed by the text screen is illustrated in FIG. 11. As may be seen, the text screen is significantly simpler than the pictorial screen and does not require rotation between color separations as is the case for pictorial screens. However, the particular text screen featured does have two rows of bricks for each brick plane.

Description of a technique for generating a look up table of rendered halftone screen values will be made with reference to FIGS. 21 and the flow chart of FIG. 22. As will become apparent the steps in the flow chart of FIG. 22 correspond to respective figure numbers in FIGS. 21. In FIG. 21-1 there is illustrated with shading a tile structure for a screen example having 141 lines per

inch at 600 dots per inch, with a 45 degree screen angle. The pixels identified as C1 represent those pixels which belong to the same tile. It will be understood that the entire image plane will be comprised of similar tiles that intermesh. It will be also understood in this example that the pixels forming the tile form one cell or super cell and that tiles may be formed having plural cells or super cells within a tile structure. In the case were the tile has plural cells or super cells there may be duplicative sets of pixel sequence numbers within a tile.

The individual pixels of the tile of this example have a unique location relative to other pixels within the tile and can be identified in this example as pixels with sequence numbers 1 through 18. Generally the shape of the tile structure and number of pixels therein and orientation of the tile is a function of the screen frequency and screen angle. In FIG. 21-2 the individual pixels in the tile are identified by the sequence numbers 1 through 18. In FIG. 21-3 the image plane is filled up with the sequence numbers of the respective tiles. In FIGS. 21-4 and 21-5 there are illustrated results of a search to find repeating rectangular blocks of sequence numbers in the image plane. As can be seen a minimum repeating block or brick is found that has a brick width (Bw) of six sequence numbers and a brick height (Bh) of 3 sequence numbers. As can also be seen the second course of bricks starts from an offset position of 3 sequence numbers, and this is referred to as brick offset or Bs.

After determining the parameters of the brick width, brick height and brick offset, the values for the look up table of rendered values may be substituted for the sequence numbers of the pixels. For this particular screen the sequence numbers for the pixels are consistent for all tile gray level values 1-255 for an eight bits per pixel system. However, for each tile gray level value a particular sequence number in the tile will correspond to a particular rendered value. This is illustrated in FIG. 21-6 which shows that for gray level 2 value for the tile that the pixel having sequence number 1 has a rendered gray level value of 106 while all other pixels in the brick have a rendered gray value of 0. In the example of the tile having a gray level of 128 it can be seen that only a few pixels in a tile have rendered values of 0 whereas other pixels have rendered pixel values other than 0.

At tile gray level 255, in this example, all pixels in the tile have a rendered value of 255.

With reference now to FIGS. 23 (a)-(c) there is illustrated the tile structure for a different screen that represents a screen structure for a tile having four cells or super cells within the tile structure. This tile structure corresponds to a screen having 171 lines per inch at 0 degrees angle of rotation. As can be seen in FIG. 23 (a) the four cells have three different shapes. A brick structure for this tile is also illustrated in FIG. 23 (a). As can be seen this brick structure has the brick height of 7 with no brick offset. In FIGS. 23 (b) and (c) the brick structure and the tile structure are illustrated with respective rendered pixel values for tile gray levels 2 and 128 for a halftone dot having a distributed dot type growth pattern. In this type of halftone dot growth pattern of gray level dots in a cell, growth tends to be distributed to several pixel members of the cell as cell gray levels increase. This growth pattern is different from the full dot type growth pattern wherein growth of cell gray level tends to increase through increasing the gray level of one pixel until the pixel becomes a maximum gray level at which point gray level growth of the cell tends to increase at a next pixel location in the cell. It will also be noted that the brick structure corresponds to the tile structure in this example.

In order to generate rendered screen values for a tile the various tile parameters such as screen angle, lines per inch, number of gray levels per pixel are considered. In addition the nature of the dot driver and dot type growth pattern are also considered. An example of a dot driver is illustrated in FIG. 24 for a 16x16 dot size driver having a circular or spiral type of growth pattern wherein dots in a cell tend to grow from the center outwardly. Other types of dot drivers may be used and suited to other shapes of growth patterns such as growth along a line, or an ellipse. These factors may be input to a dot membership function generator which considers cells within a tile and the contribution of spill over exposure at a pixel location of exposures from other pixel locations from other cells forming a part of the tile. A screen profile builder may then be used to determine the total gray level in the tile by summing of the exposure values at pixel locations that are not yet quantized. A screen profile quantizer then quantizes the individual pixel rendered values so that these values can be

expressed in a form of a whole number, for example, 0-255 in a system having an eight bits per pixel bit depth.

It will be understood of course as described herein an assignment of a rendered screen value does not imply that this is a value that is output directly to a printer as other image processing operations may be implemented upon the rendered screen values obtained. Thus as described herein a rendered screen value for a particular pixel may be subjected to thresholding to establish eligibility for further processing such as edge enhancement processing or to a blending operation.

A functional block diagram of a one example of an edge enhancement processing system that may be used in the method and apparatus of the invention is illustrated in FIG. 12. As noted above, the input into the GRET processor 28 is in the form of a binary bitmap through adjustment by GRET adjustable threshold/detector 26. This is with regard to data that has been subject to thresholding. The data output by the blending operation processor 24 is also bypassed to the GRET or bypass selection device 32. The input into the GRET processor 28 is a binary bitmap where the term "binary" bitmap or image is understood by those skilled in the art to refer to a bitmap or image in which image pixels are either fully or substantially fully exposed or are unexposed or substantially unexposed, i.e., substantially no gray-scale pixel data is present. As the GRET processor, in this example, may process pixels at a bit depth of four bits per pixel, the detector 26 may modify the eight bits per pixel image data into the four bits per pixel bit depth required by the GRET processor. The term "gray-scale" refers to image data wherein each pixel is represented by more than one bit of data to indicate one or more shades of gray between fully exposed and fully unexposed. Of course, the actual color of the pixel will be dependent upon the color toner or pigment used in a printing process to develop the pixel. As an example where image data is represented by four binary bits of information, a binary bitmap will have image data represented by either 0 or 15. The binary bitmap includes rows and columns of this image data wherein 0 may represent an unexposed pixel and 15 may represent the pixel area being fully exposed. Of course, these can be reversed. Development is preferably at the exposed pixel

area and no development at the unexposed pixel area (known as discharged area development or reversal development but alternatively charged area development may be used). While reference herein is made to "exposed" and "unexposed" pixels, it will be understood that in other printing or display systems equivalent representation of pixels will be provided according to the nature of the system, even though the nature of the system does not employ an exposure, for example, inkjet which employs a deposit of ink.

In the GRET processor 28 the current pixel position as output from a band buffer 100 is indicated by the term n(i,j). Sobel gradient masks 120,140 for both the horizontal and vertical directions operate on the binary bitmap data n(i,j) to produce a gradient x operator (gx) and a gradient y operator (gy). Typical sobel gradient masks that can be employed include those described in U.S. Patent No. 6,021,256, the contents of which are incorporated herein by reference. Other gradient masks may also be used. The gradient amplitude or magnitude (gm) is then calculated by a processor 160 by taking the square root of the sum of the square of the gradient x operator (gx) and the square of the gradient y operator (gy) for each location in the bitmap to produce a gradient magnitude map. The gradient magnitude map is then stored in a buffer 180 for later use. Similarly, the gradient angle (ga) 220 is determined for each pixel location to produce a gradient angle map 220. For purposes of convenience, the gradient angle (ga) is preferably limited to a choice of gradient directions (gd) by a gradient directions sorter 240. The gradient direction for each location is stored in a buffer 260. The original bitmap data and the gradient magnitude (gm) and gradient direction (gd) corresponding thereto are supplied to a decision matrix 280, which uses this information to select edge enhanced gray-scale output data to replace the binary bitmap data entering the GRET processor. The decision matrix 280 determines whether the central pixel of a window of the binary bitmap data is a black or white pixel, whether the central pixel is contained in a single pixel line and the position of the pixel with respect to a kink site, by comparing the pixel data to a set of criteria represented by predetermined pixel values and gradient magnitudes. In accordance with rules establishing a set of criteria, the decision matrix 280 generates an address that is supplied to a look-up table LUT 30. The LUT 30

generates edge enhanced gray-scale output data based on the address generated by the decision matrix 280. The enhanced gray scale output data replaces the binary input data output by the threshold/detector 26 and produces a smoother image without jagged edges when applied to a gray scale printhead (for example, a laser, LED, thermal, inkjet or other type of printhead) of a printer or to a gray level display such as a CRT or other suitable display. It will be understood that the GRET system can be implemented as a computer program executed on a general-purpose computer or a dedicated programmed computer or in hardware as a pipeline processing system, particularly in the form of an application-specific integrated circuit (ASIC), or a combination thereof. The LUT 30 as noted in FIG. 1 may be a series of high/medium/low LUTs 30 each of which may be selected by input of a GRET strength selector signal to provide preferences for the type of or strength of edge enhancement.

Variable Strength GRET

With reference now to FIGS. 13 and 14-17 there will now be provided a description of the operation of the variable strengthening of the GRET output. In FIG. 14 there is illustrated an original image that is binary and represented by eight bits per pixel so that the value 255 represents pixel areas where there will be maximum development while pixel areas indicated as 0 represents no development or background. The image represents various lines emanating from an origin location that run at different angles relative to the origin. It will be noted that there is a staircasing effect or jaggedness in certain of these radiating lines, and it is an object of this resolution enhancement device to attempt to minimize this jaggedness by placement of gray level pixels at particular sites at the periphery of the lines to provide an appearance of relative smoothness. Consider now FIG. 15 wherein there is shown a GRET output wherein the lookup table 30 is adjusted for medium strength. In now comparing FIGS. 16 and 17 with that of FIG. 15, it will be noted that for cases of GRET output using a high-strength lookup table the gray level values added by the GRET processor are different for the cases of high-strength, medium strength and low strength. It will also be noted that values that are binary in nature; i.e., 0 or 255, are not affected. Thus, this

provides an additional adjustment to the operator at the workstation WS in allowing for personal preference input adjustments by the operator towards improvements in anti-aliasing. The operator merely selects which option of LUT 30 (high, medium, low strength) he/she prefers to improve on reduction in jaggedness.

Adjustable Threshold Input for GRET Processing

In FIG. 19 there is shown a printer or display apparatus 400 which includes the image processing system 10 described above. The apparatus includes a document that is scanned by a scanner 410 which generates an 8-bit signal representing density scanned. The raw scanned image data typically in the form of red, green, blue (R,G,B) may be buffered in a buffer 412 and is then subject to color and other image processing such as gamma correction 414. When the image data is in the form of one color system there is a need to convert the color image data to a different color system by a color transformation operation 416. The transformed color separation image data normally used with a printer is preferably C,Y,M,K. As noted above, the color transformation processor may be provided with under color removal and/or gray component replacement as is well known. The function of under color removal is mainly to reduce chromatic color (yellow, magenta and cyan) in the dark or near-neutral shadow areas in order to reduce toner height or toner coverage. Gray component replacement is similar but refers to use of black toner for the gray component of any color and is not restricted as is under color removal to the near-neutral color area. Although the purpose of these two techniques are different, in reality they are similar in terms of employing black toner to reduce some of the chromatic toners from the image. With reference now to FIGS. 20 (a) and (b), there is provided an example of GCR and UCR with a brown mixed color. The GCR function permits the gray component of the chromatic printing inks or toners to be replaced by black process color, with an effect in the entire color space. The amount replaced can be set as desired. The color impression remains the same. Less color is needed to create a specific hue, i.e., the area is reduced. This means that the gray axis is more stable. Since fewer chromatic colors are used, cost can be reduced. UCR is an additional or

optional setting option in chromatic reproduction. In this process, the gray component of the chromatic printing inks or toners is replaced by black in neutral image shadow. Less color is needed to create a specific hue, i.e., the area is reduced. This means that the gray axis is more stable and fewer chromatic colors are used, cost can be reduced with UCR as well. Although it is known to provide a UCR and/or GCR processor after color space transformation, it is more preferable to provide for it during the color space transformation. A problem associated with employing UCR and/or GCR is that the most saturated color values produced by the processing may not reach the levels that would otherwise indicate that they represent binary data image information. For example, the threshold/detector 26 is provided with a certain preprogrammed threshold level values above the threshold level assumed to be binary information. If certain color transformation processes are employed in which all the process information falls below this preprogrammed threshold level, then all the information will be assumed to be a non-binary image data file and will be subject to bypass of the GRET processor. The operator of the printer will be aware of the color transformation processes being employed and can therefore through adjustment of the threshold input to the GRET adjustable threshold/detector 26 provide for a new threshold level taking into account what will substantially be considered a useful threshold above which would indicate a binary image data file . For example, typically a binary image file might be represented by saturated color gray values in an 8-bit depth system wherein the gray values are considered to be 254 or 255. Thus, a threshold value of 253 might be established in the threshold/detector 26. However, particularly where UCR and/or GCR are employed, maximum gray values may be no more than 253. The indication would, thus, be that no binary image data file is present and selection would be made of only data that has bypassed the GRET processor. However, this result belies the nature of the image information because of the nature of the processing in the color transformation. In order to overcome this problem, the operator is provided an opportunity through a programmed adjustable threshold input to establish a new threshold for determining what is defined to be a binary image data file so that improved control is now provided between which image data will

be subject to selection either data that has bypassed the GRET processor or image data which is subject to GRET processing. Thus, for example, where UCR and/or GCR are employed the operator would establish a lower threshold than say 253 for the GRET threshold/detector 26 in order to be sure that some of the information selected for output would be that from the GRET processing. Alternatively, a lower threshold may be established by altering the threshold value automatically upon selection by the operator of under color removal and/or gray component replacement or an adjustment in the amount of under color removal and/or gray component replacement.

The raw scanned image data may be subject also to other corrections as is well known in the prior art. Input from an electronic data source 420 may also be provided of pages of image data that may also be input to a job image buffer 424 after rasterization by a raster image processor (RIP) 422. One or more pages of rasterized image data from the scanner or the electronic data source are stored in the job image buffer (JIB), preferably in compressed form, allowing collated sets of multipage documents to be printed by electronically recirculating the image data in the job image buffer after the data has been sent to the printer. In this regard reference may be had to U.S. Patent No. 5,047,955 filed in the name of Shope et al, the contents of which are incorporated herein by reference. The image data is output to an image processing system 10 described above for ultimate output to a gray level printhead or display 470. The printhead may be provided with correction by a writer interface board 460 for correcting for nonuniformities of the recording elements or other known correction devices or schemes such as those which adjust exposure level through pulse-width modulation, pulse intensity modulation, etc. In this regard reference is made to U.S. Patent No. 6,021,256, filed in the name of Ng et al, and U.S. Patent No. 5,914,744, filed in the name of Ng. Overall control of the apparatus may be provided by marking engine controller 426 that may be in the form of one or more microcomputers suitably programmed to provide the control in accordance with well-known programming skills. A workstation WS provides input to the marking engine controller of various job parameters relative to the printing job, such as number of copies, paper selection, etc., including the GRET adjustable threshold

input value used by the detector 26, GRET strength selection (high, medium, low LUT) and the real-time color tweaking adjustment used in LUT 12.

In the preferred apparatus of the invention the printhead of say 600 dpi resolution exposes a uniformly charged photoconductive drum or web and the web is developed with pigmented electroscopic toner particles to develop the image. The developed image, as well as developed images of other color separations, are then transferred either serially in separate operations or in one operation to a receiver sheet either directly from the photoconductive web or drum or indirectly via an intermediate transfer member and in this regard reference is made to U.S. Patent No. 6,075,965, issued in the name of Tombs et al, for description of a color electrophotographic machine for serially transferring color separation images to a receiver sheet.

Extension of this method includes storing more than one pictorial screen within one of the screeners, so different pictorial screens can be used within the printed page (or the next page without reloading the screener LUT). Of course, in this case one will need to store more than one set of screen addresses (in the Row and Column LUTs). Also a selector function at say the workstation WS of which pictorial screen to use will need to be included.

Other extensions on the subject include the usage of an irrational screen coordinate calculator (the errors for screen angle and frequency calculation can be propagated forward, so adjustment of subsequent screen blocks can be done to correct for those errors), such that irrational screens can be used and one can obtain more choices of accurate screen angles and frequencies using this method with a lower addressability output device. In more detail, the screen coordinate calculator calculates the LUT data addresses for each step through the screen brick, and accumulates a position error due to stepping through the brick. This position error is corrected by making address jumps when a pre-defined position error threshold is exceeded.

There has thus been described an improved apparatus and method wherein a gray level image data file which may contain pictorial or non-saturated text images and saturated text images and that these respective images may be

provided with respective halftone processing and other processing that reduces anti-aliasing effects.

The invention has been described with reference to certain preferred embodiment thereof. It will be understood, however, and modifications and variations can be made within the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A method for processing gray level image data comprising :

subjecting the gray level image data to halftone screen processing to form halftone processed screen image data;

analyzing a current pixel of the halftone processed screen image data to a test criterion to determine if the current pixel is a possible saturated color text image; and

if the current pixel meets the criterion for being a pixel of a possible saturated color text image selecting the gray level image enhanced processing modification of the current pixel for output to a printer or display; and

if the current pixel does not meet the test criterion for being a pixel of a possible saturated color text image selecting the current pixel gray level value as processed by the halftone screen processing for output to a printer or display.

2. The method according to claim 1 wherein the gray level image data is processed independently through plural halftone screen processors and the output of the two processors are blended.

3. The method according to claim 2 wherein in the step of analyzing the current pixel and plural neighboring pixels to the current pixel are examined relative to a threshold.

4. The method according to claim 3 wherein the threshold is adjustable.

5. The method according to claim 4 wherein one of the screen processors has a screen frequency of at least 200 lines per inch.

6. The method according to claim 5 wherein a current pixel meeting the criterion of being a saturated color text image has its gray level value adjusted to a maximum value before being processed by gray level enhanced processing.

7. The method according to claim 6 wherein in gray level enhanced processing a substantially binary image file is modified to add gray level pixels of a density less than maximum density to provide smooth edge transitions.

8. The method according to claim 1 wherein in gray level enhanced processing a binary image file is modified to add gray level pixels of a density less than maximum density to provide smooth edge transitions.

9. The method according to claim 8 wherein the image data represents image data of a color separation file.

10. The method according to claim 9 wherein the image data is adjusted for color saturation according to a personal preference.

11. The method according to claim 10 wherein the image data is analyzed for contrast and in response to analysis for contrast blending coefficients are generated and the image data that is adjusted for color saturation is independently subjected to separate halftone screen processing with screens of different halftone frequencies and outputs of the processing by the different halftone screen processings are each modified by a respective blending coefficient.

12. The method according to claim 8 wherein the resolution enhancement processor is adjustable to provide for different levels of smoothing of edges.

13. A method for processing gray level image data comprising:

subjecting first gray level image data to plural separate halftone screen processings to form plural separate halftone screen processed gray level image data;

analyzing a current pixel of the first gray level image data for contrast index;

in response to the analyzing generating blending coefficients for processing that current pixel ;

processing the plural separate halftone screen processed image data with the blending coefficients to blend halftone screen processed gray level image data of the same current pixel to form a blended halftone screen processed gray level current pixel;

comparing the gray level of the blended halftone screen processed current pixel relative to a threshold criterion; and

if the gray level of the blended halftone screen processed current pixel meets the threshold criterion providing a gray level image enhanced processing modification of the current pixel for output to a printer or display; and

if the gray level of the blended halftone screen processed current pixel does not meet the threshold criterion providing the current pixel gray level as processed by the halftone screen processing for output to a printer or display.

14. The method according to claim 13 wherein in the step of determining if the gray level of the blended halftone screen processed current pixel meets the threshold criterion there are also examined gray levels of blended halftone screen processed neighboring pixels to the current pixel.

15. The method according to claim 14 wherein the threshold is adjustable.

16. The method according to claim 15 wherein the first gray level image data is color separation image data and prior to subjecting the first gray level image data to plural separate halftone screen processing the gray level image data is subject to processing for gray component replacement or undercolor removal.

17. The method according to claim 16 wherein the current pixel meeting the threshold criterion has its gray level value adjusted to a maximum value before being processed by gray level enhanced processing.

18. The method according to claim 17 wherein one of the screen processors has a screen frequency of at least 200 lines per inch.

19. The method according to claim 13 wherein in gray level enhanced processing a substantially binary image file is modified to add gray level pixels of a density less than maximum density to provide smooth edge transitions.

20. An apparatus for processing gray level image data comprising:

first and second halftone screen processing devices that form plural separate halftone processed screen gray level image data;

an input to each of said screen processing devices to input image data representing a current gray level pixel;

a device for analyzing the current pixel for contrast index;

a device responsive to the contrast index for generating blending coefficients;

a blending operation processor that generates a blended halftone data output for the current pixel;

an input at the blending operation processor for inputting respective outputs of the first and second halftone screen processing devices and the blending coefficients;

a gray level image enhancement processing device connected to the output of the blending operation processor;

a detector for examining the current pixel after operation by the blending processor and neighboring pixels thereof after operation of the blending processor and determining if the current pixel and such neighboring pixels represent a substantially binary image file and generating a signal relative to such determination; and

a selector , responsive to the signal, that selects either the gray level image enhancement processing device output or a bypass representing a blended halftone data output.

21. A method for processing gray level image data comprising:

subjecting first gray level image data to plural separate halftone screen processings to form plural separate halftone screen processed gray level image data;

blending halftone screen processed gray level image data of the same current pixel to form a blended halftone screen processed gray level value current pixel; and

if the blended halftone screen processed gray level value current pixel is substantially a maximum density pixel or is adjusted to be a substantially maximum density pixel subjecting the blended halftone screen processed gray level current pixel to a gray level image enhanced processing modification to reduce jaggedness in an image.

22. The method according to claim 21 wherein the plural separate halftone screen processings include a halftone screen processing employing a partial dot growth pattern and a halftone screen processing employing a mix dot growth pattern.

23. The method according to claim 21 wherein the plural separate halftone screen processings comprise a halftone screen processing suitable for a text type image and a halftone screen processing suitable for a pictorial image.

24. The method according to claim 21 wherein the plural halftone screen processed gray level image data is blended according to blending coefficients.

Docket # 95-0601

EDGE ENHANCEMENT OF GRAY LEVEL IMAGES

Abstract of the Disclosure

A method and apparatus for processing gray level image data. Gray level image data is subjected to plural separate halftone screen processing to form plural separate halftone processed screen gray level image data. The current pixel is also analyzed for contrast index. In response to analysis of the contrast index blending coefficients for processing of the halftone screen modified image data is made. The respective halftone outputs of the screen processings are multiplied by the respective blending coefficient. The resulting blended halftone gray value of the current pixel as well as neighboring pixels are then subjected to a threshold criterion test to determine if this represents a substantially binary image file such as might occur in a saturated text image file. The blended halftone gray value data for the current pixel is subjected to gray level edge enhancement processing to replace certain binary pixels adjacent an edge to reduce anti-aliasing effects. A signal resulting from the threshold criterion test is used to determine whether there is output to the printer or display of an edge enhanced version of the current blended halftone pixel or a pixel value representing the blended halftone pixel.

Figure 1

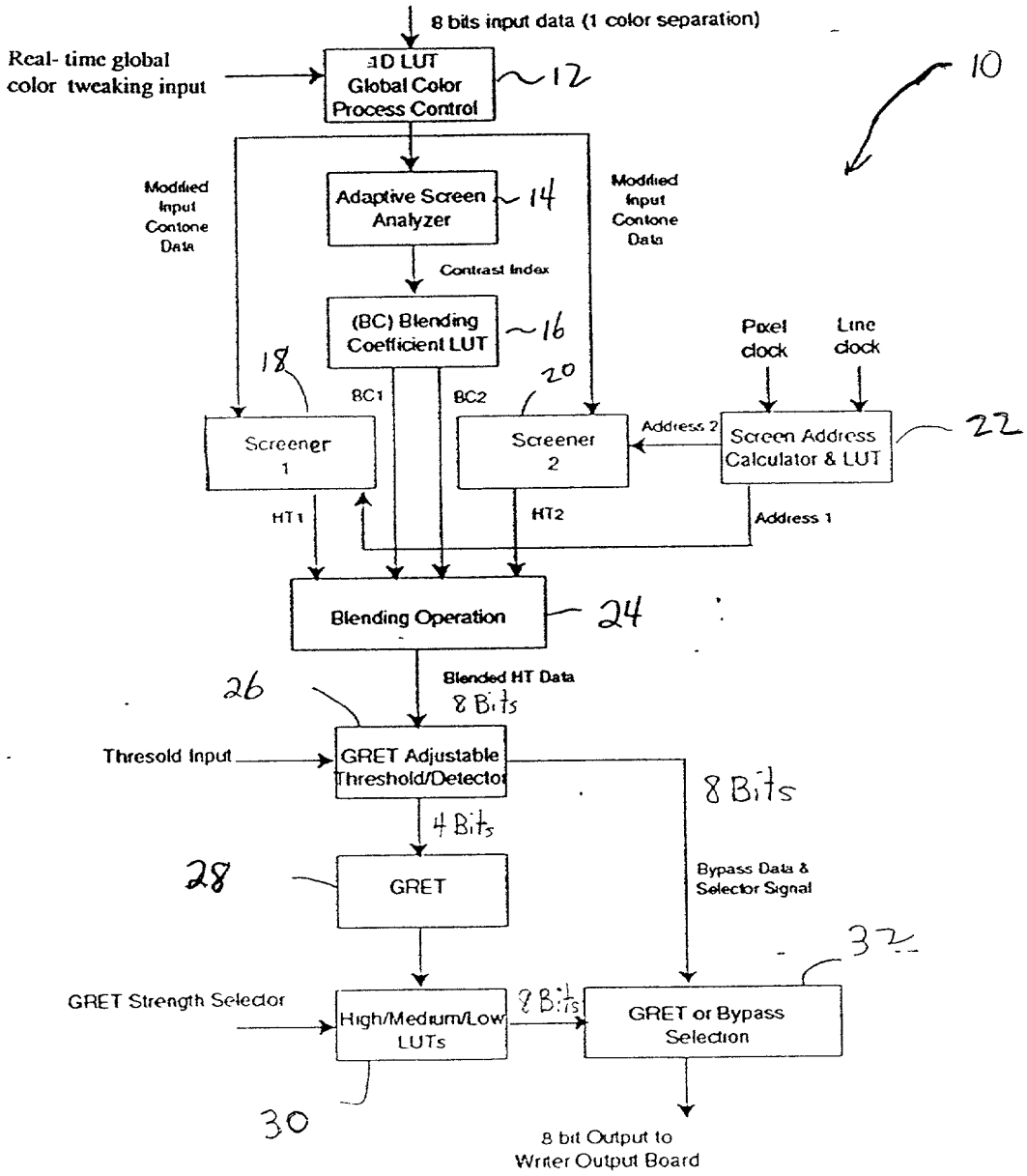
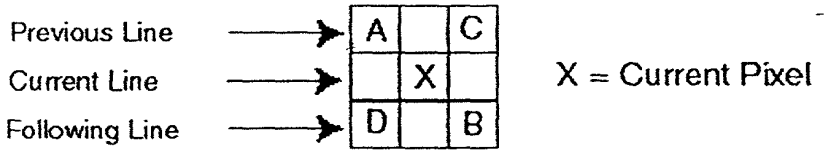
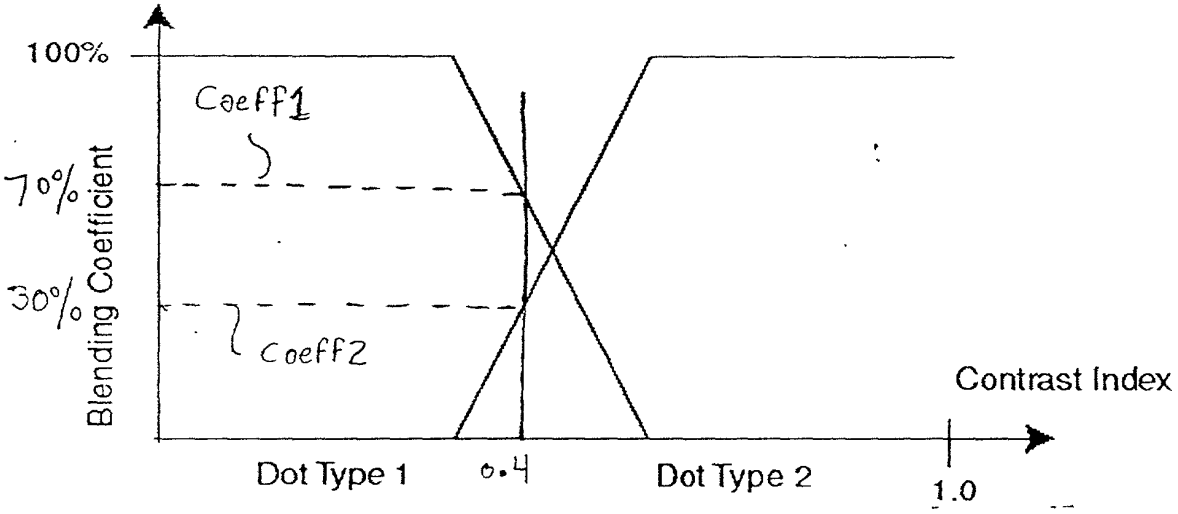

8 bits input data (1 color separation)
Real- time global color tweaking input
3D LUT Global Color Process Control
12
10
Modified Input Contone Data
Adaptive Screen Analyzer
14
Modified Input Contone Data
Contrast Index
(BC) Blending Coefficient LUT
16
Pixel clock
Line clock
18
BC1
BC2
20
Screener 1
Screener 2
Address 2
Screen Address Calculator & LUT
22
HT1
HT2
Address 1
Blending Operation
24
Blended HT Data
8 Bits
26
Thresold Input
GRET Adjustable Threshold/Detector
8 Bits
4 Bits
28
GRET
Bypass Data & Selector Signal
32
GRET Strength Selector
High/Medium/Low LUTs
8 Bits
GRET or Bypass Selection
30
8 bit Output to Writer Output Board

Figure 2



Contrast Index = Max (| A - B |, | C - D |)

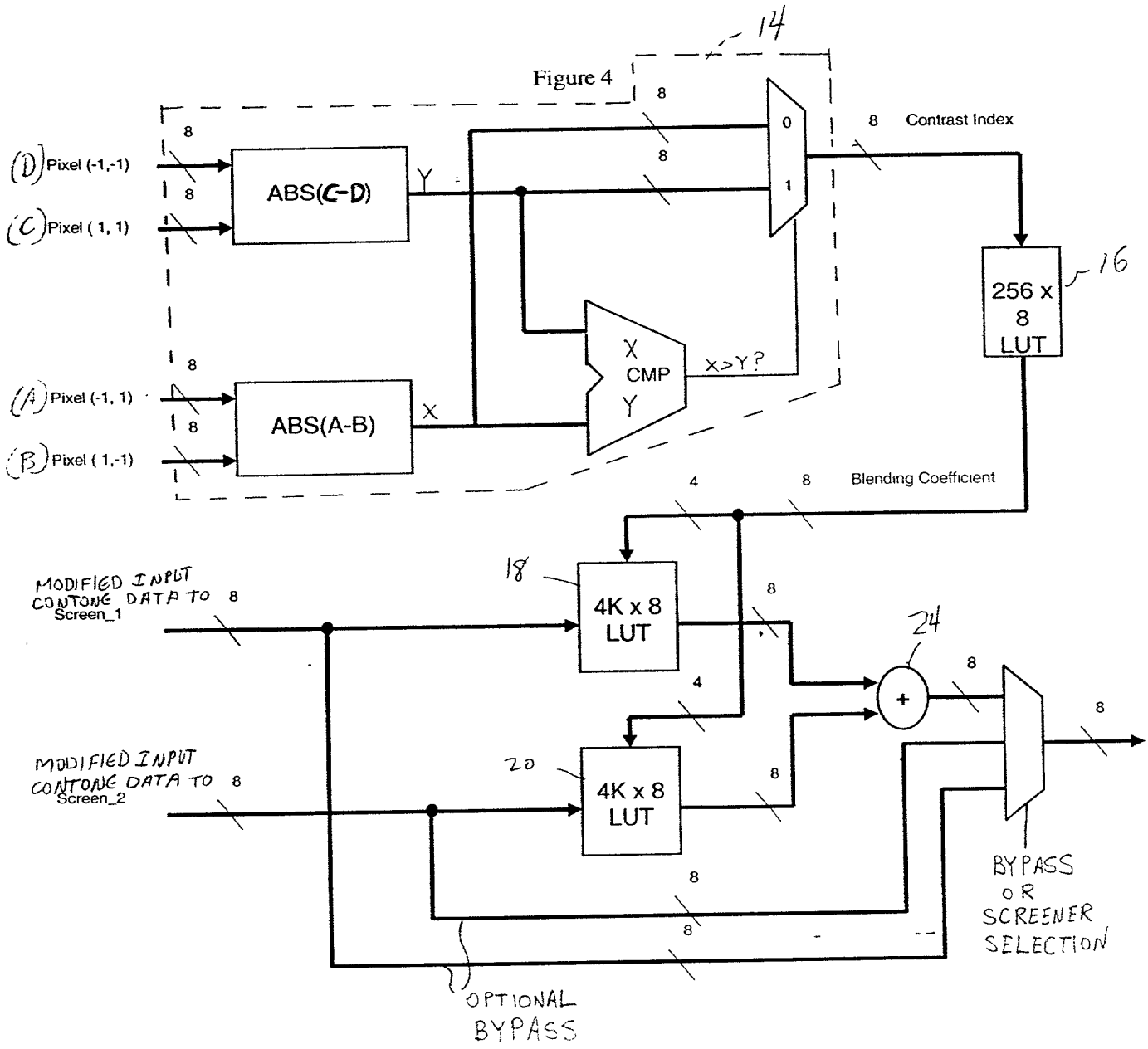
Figure 3



Rendered Dot Value = (Dot1_value) x Coeff1 + (Dot2_value) x Coeff2)

Coeff1 + Coeff2 = 1.0

Figure 4


14
(D) Pixel (-1,-1)
(C) Pixel (1, 1)
ABS(C-D)
Y
8
8
0
1
8 Contrast Index
(A) Pixel (-1, 1)
(B) Pixel (1,-1)
ABS(A-B)
X
X CMP Y
X>Y?
256 x 8 LUT
16
4
8 Blending Coefficient
MODIFIED INPUT CONTONE DATA TO Screen_1
18
4K x 8 LUT
24
+
MODIFIED INPUT CONTONE DATA TO Screen_2
20
4K x 8 LUT
BYPASS OR SCREENER SELECTION
OPTIONAL BYPASS

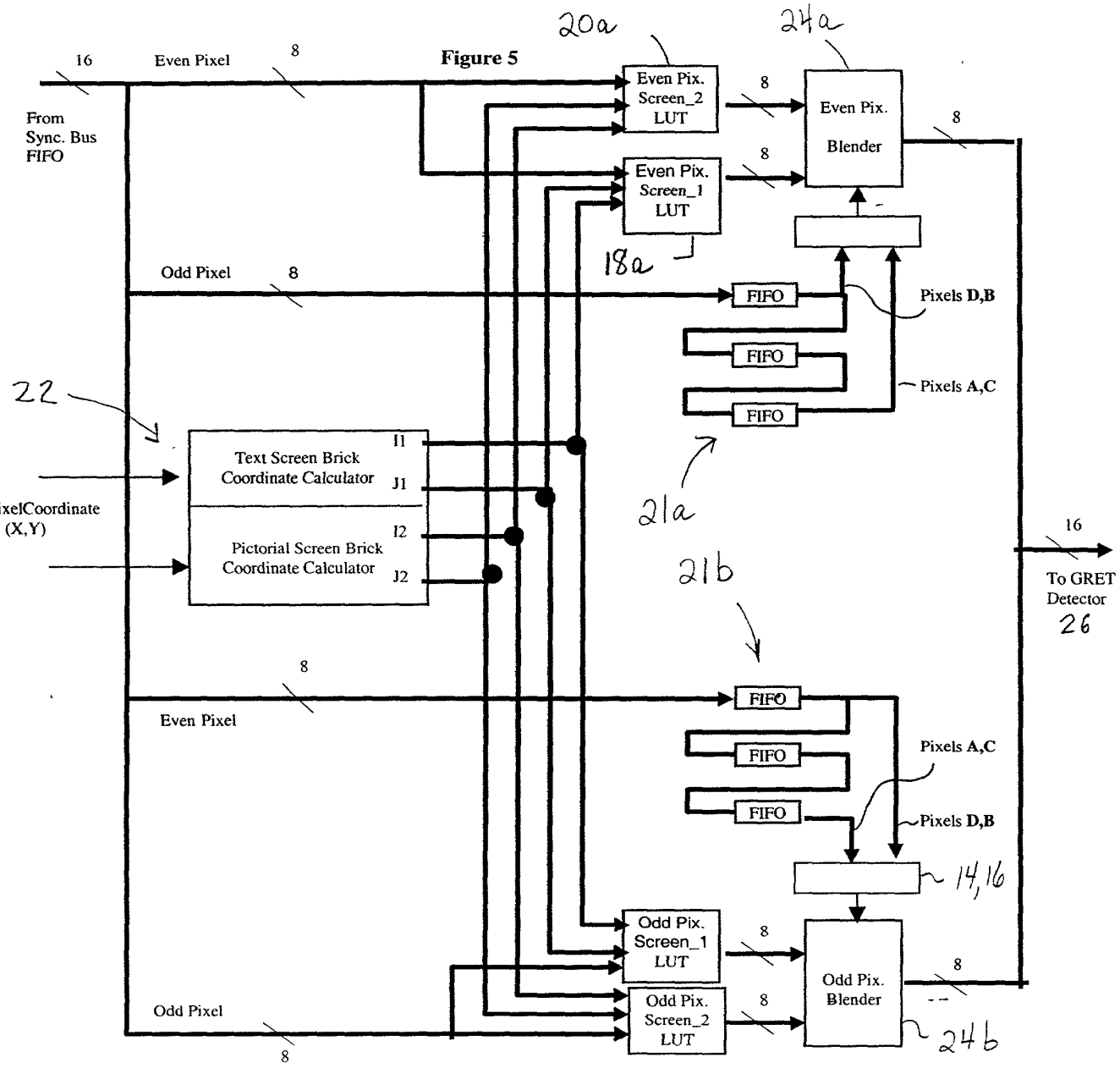


Figure 5
20a
24a
16
Even Pixel
8
From Sync. Bus FIFO
Even Pix. Screen_2 LUT
Even Pix. Screen_1 LUT
Even Pix. Blender
8
18a
Odd Pixel
FIFO
Pixels D,B
Pixels A,C
22
Text Screen Brick Coordinate Calculator
Pictorial Screen Brick Coordinate Calculator
I1
J1
I2
J2
PixelCoordinate (X,Y)
21a
21b
16
To GRET Detector
26
Even Pixel
Odd Pixel
Odd Pix. Screen_1 LUT
Odd Pix. Screen_2 LUT
Odd Pix. Blender
14,16
24b

Screen LUT Illustration

Plane = 255

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	255	255	255	255	0	0	0
2	0	0	0	0	0	0	0	0	255	255	255	255	255	255	255	255	0	0	0
3	0	0	0	0	255	255	255	255	255	255	255	255	255	255	255	255	0	0	0
4	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0	0
5	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0	0
6	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0	0
7	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0	0
8	0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0
9	0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0
10	0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0
11	0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0
12	0	0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
13	0	0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
14	0	0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
15	0	0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
16	0	0	0	0	255	255	255	255	255	255	255	255	255	255	255	255	0	0	0
17	0	0	0	0	255	255	255	255	255	255	255	255	0	0	0	0	0	0	0
18	0	0	0	0	255	255	255	255	0	0	0	0	0	0	0	0	0	0	0

Fig. 6(a)

Plane= 128

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	9	166	117	32	0	0	0
2	0	0	0	0	0	0	0	0	0	120	155	40	77	233	248	187	0	0	0
3	0	0	0	0	0	70	182	57	48	204	253	209	156	219	241	83	0	0	0
4	0	32	187	83	32	163	253	228	155	202	248	132	0	54	168	32	0	0	0
5	0	117	248	241	168	182	243	181	22	27	152	70	0	13	182	163	70	0	0
6	0	166	233	219	54	13	117	116	0	0	134	194	81	117	243	253	182	0	0
7	0	0	86	156	0	0	81	212	104	86	225	255	212	116	181	228	57	0	0
8	0	0	40	209	132	70	194	255	235	126	157	235	104	0	22	155	48	0	0
9	0	0	155	253	248	152	134	225	164	0	0	133	86	0	27	202	204	120	0
10	0	0	120	204	202	27	0	86	133	0	0	164	225	134	152	248	253	155	0
11	0	0	0	48	155	22	0	104	235	157	126	235	255	194	70	132	209	40	0
12	0	0	0	57	228	181	116	212	255	225	86	104	212	81	0	0	156	86	0
13	0	0	0	182	253	243	117	81	194	134	0	0	116	117	13	54	219	233	166
14	0	0	0	70	163	182	13	0	70	152	27	22	181	243	182	168	241	248	117
15	0	0	0	0	32	168	54	0	132	248	202	155	228	253	163	32	83	187	32
16	0	0	0	0	83	241	219	156	209	253	204	48	57	182	70	0	0	0	0
17	0	0	0	0	187	248	233	86	40	155	120	0	0	0	0	0	0	0	0
18	0	0	0	0	32	117	166	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 6(b)

Plane= 2

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	12	34	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	47	0	0	11	30	0	0	0	0
4	0	0	0	0	0	0	36	11	0	0	42	0	0	0	0	0	0	0	0
5	0	0	24	23	0	0	32	10	0	0	0	0	0	0	0	0	0	0	0
6	0	0	22	20	0	0	0	0	0	0	0	0	0	0	18	51	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	68	0	0	5	14	0	0	0
8	0	0	0	0	0	0	0	52	16	0	0	19	0	0	0	0	0	0	0
9	0	0	0	35	33	0	0	15	4	0	0	0	0	0	0	0	0	0	0
10	0	0	0	10	9	0	0	0	0	0	0	0	0	0	0	24	64	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	88	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	67	21	0	0	0	0	0	0	0	0	0
13	0	0	0	0	45	42	0	0	0	0	0	0	0	0	0	0	6	18	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	17	46	0
15	0	0	0	0	0	0	0	0	0	19	6	0	0	63	0	0	0	0	0
16	0	0	0	0	0	12	12	0	0	49	15	0	0	0	0	0	0	0	0
17	0	0	0	0	0	33	31	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig 6(c)

Example of 19x19 size of screen tile **(Screen ruling : 154.6 LPI** **Screen Angle : 14.93)**

1. Brick Width = 241 2. Brick Height = 1 3. Brick Offset = 177

Plane 255

255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255

Fig. 7(a)

Plane 128

0	0	0	0	0	0	81	20	0	1	35	0	0	0	0	0	0	0	1	1	0	0	101	24	0	0	3
0	0	0	0	0	0	0	17	16	0	0	82	21	0	0	0	0	0	0	0	0	0	0	35	32	0	0
53	16	0	0	0	0	0	0	0	0	0	0	52	48	0	0	24	5	0	0	0	0	0	0	0	1	0
0	68	57	0	0	2	1	0	0	0	0	0	0	6	21	0	0	54	50	0	0	0	0	0	0	0	0
0	0	18	49	0	0	36	34	0	0	0	0	0	0	0	0	0	0	24	70	0	0	18	17	0	0	0
0	0	0	0	2	0	0	35	96	0	0	2	2	0	0	0	0	0	0	1	32	0	0	25	73	0	0
0	0	0	0	0	0	0	0	1	65	0	0	18	51	(0)	0	0	0	0	0	0	0	0	0	2	98	0
0	6	23	0	0	0	0	0	0	0	1	0	0	3	128	0	0	1	2	0	0	0	0	0	0	0	22
4	0	2	101	0	0	0	0	0	0	0	0	0	0	0	51	9	0	1	68	0	0	0	0	0		

Fig. 7(b)

Plane 2

0	0	0	0	0	0	51	14	0	1	23	0	0	0	0	0	0	0	1	1	0	0	65	18	0	0	3
0	0	0	0	0	0	0	11	10	0	0	52	15	0	0	0	0	0	0	0	0	0	0	23	20	0	0
35	10	0	0	0	0	0	0	0	0	0	0	34	30	0	0	18	5	0	0	0	0	0	0	0	1	0
0	44	39	0	0	2	1	0	0	0	0	0	0	6	15	0	0	36	32	0	0	0	0	0	0	0	0
0	0	12	31	0	0	24	22	0	0	0	0	0	0	0	0	0	0	18	46	0	0	12	11	0	0	0
0	0	0	0	2	0	0	23	60	0	0	2	2	0	0	0	0	0	0	1	20	0	0	19	49	0	0
0	0	0	0	0	0	0	0	1	41	0	0	12	33	(0)	0	0	0	0	0	0	0	0	0	2	62	0
0	6	17	0	0	0	0	0	0	0	1	0	0	3	80	0	0	1	2	0	0	0	0	0	0	0	16
4	0	2	65	0	0	0	0	0	0	0	0	0	0	0	33	9	0	1	44	0	0	0	0	0		

Fig. 7(c)

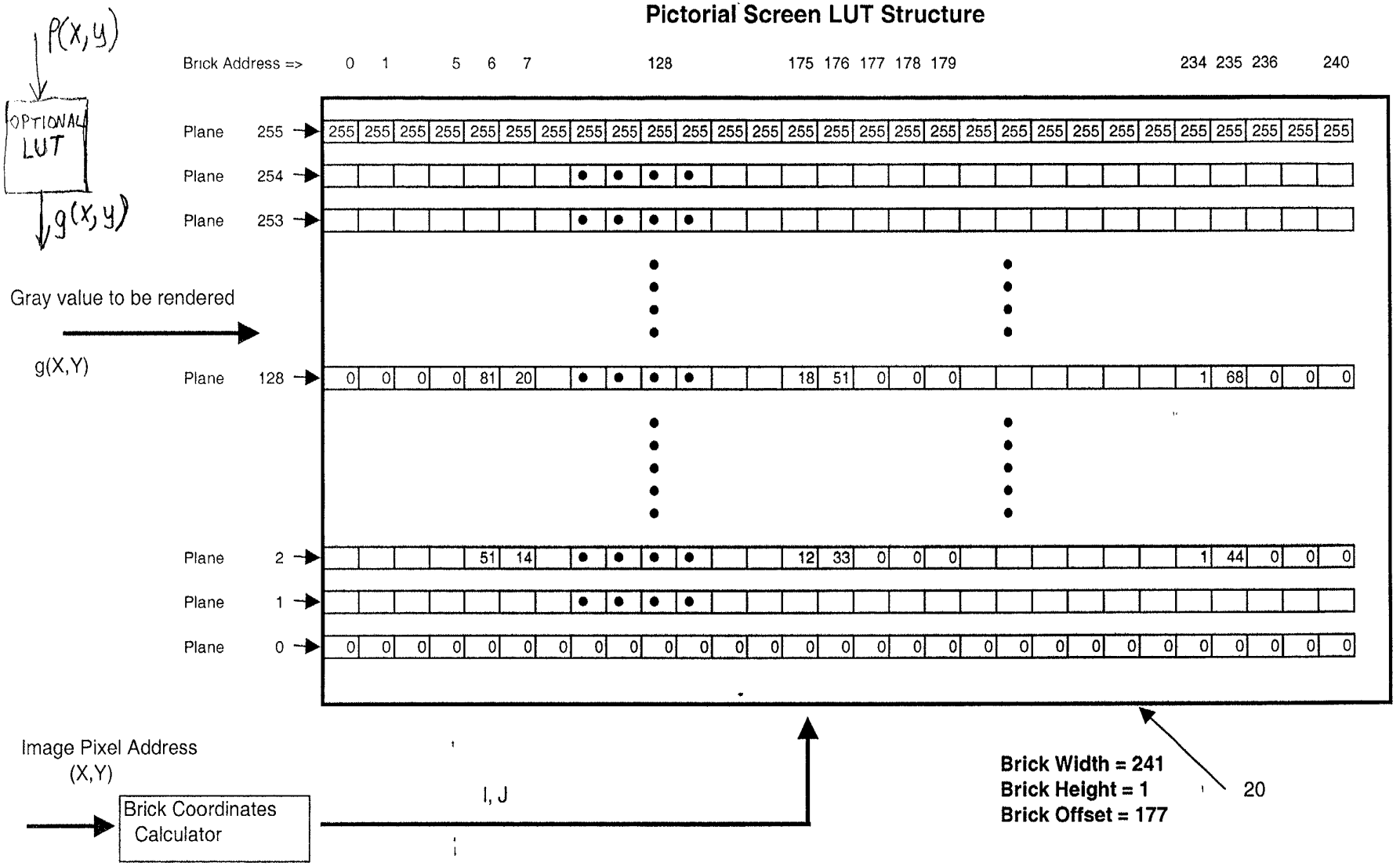

Pictorial Screen LUT Structure
P(X,Y)
OPTIONAL LUT
g(X,Y)
Brick Address => 0 1 5 6 7 128 175 176 177 178 179 234 235 236 240
Plane 255
Plane 254
Plane 253
Gray value to be rendered
g(X,Y)
Plane 128
Plane 2
Plane 1
Plane 0
Image Pixel Address (X,Y)
Brick Coordinates Calculator
I, J
Brick Width = 241
Brick Height = 1
Brick Offset = 177
20

Fig. 8

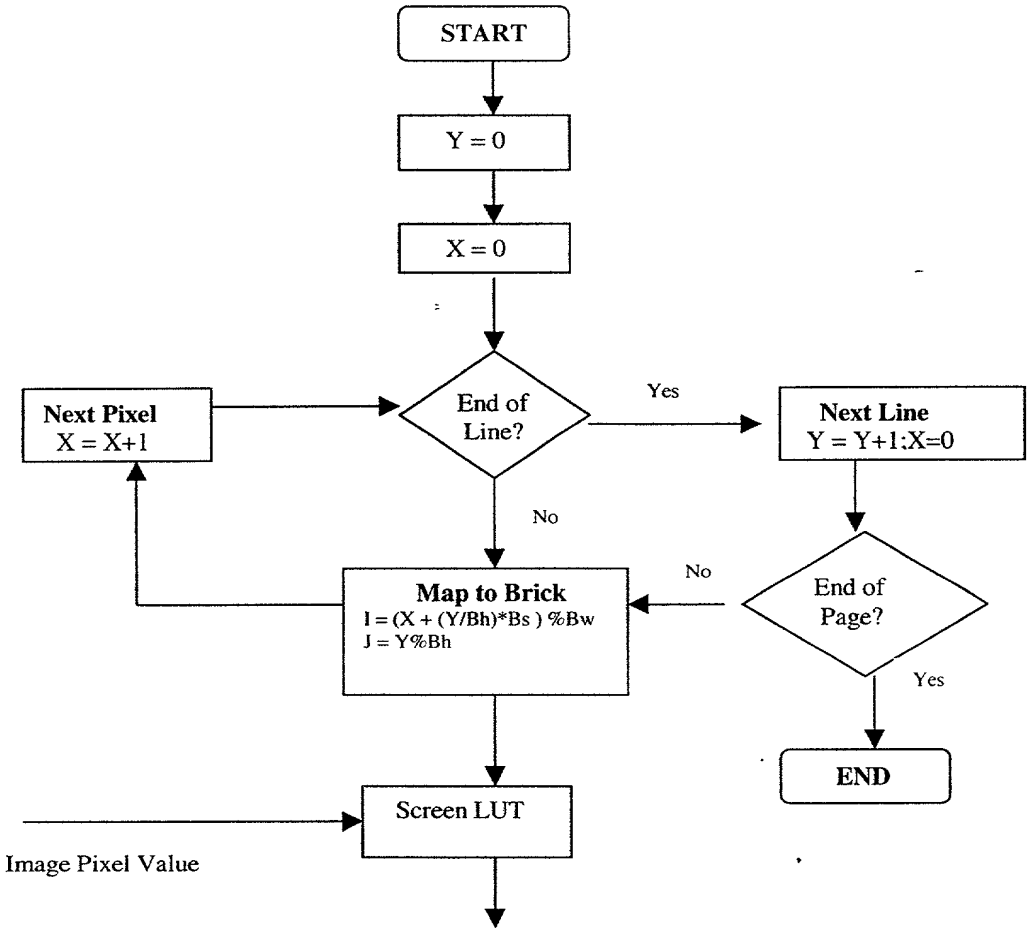


Figure: Screening Operation Flow Diagram
(X,Y: Image Pixel address; I,J: Brick address)
(Bw: Brick width; Bh: Brick height; Bs: Brick offset)

Fig. 9

Example of 2x2 size of Text screen tile (Screen ruling : 300 LPI Screen Angle : 0)

1. Brick Width = 2

2. Brick Height = 2

3. Brick Offset = 0

Plane 255

255	255
255	255

Plane 128

127	128
128	128

Plane 2

1	2
2	2

Fig. 10

Text Screen LUT Structure

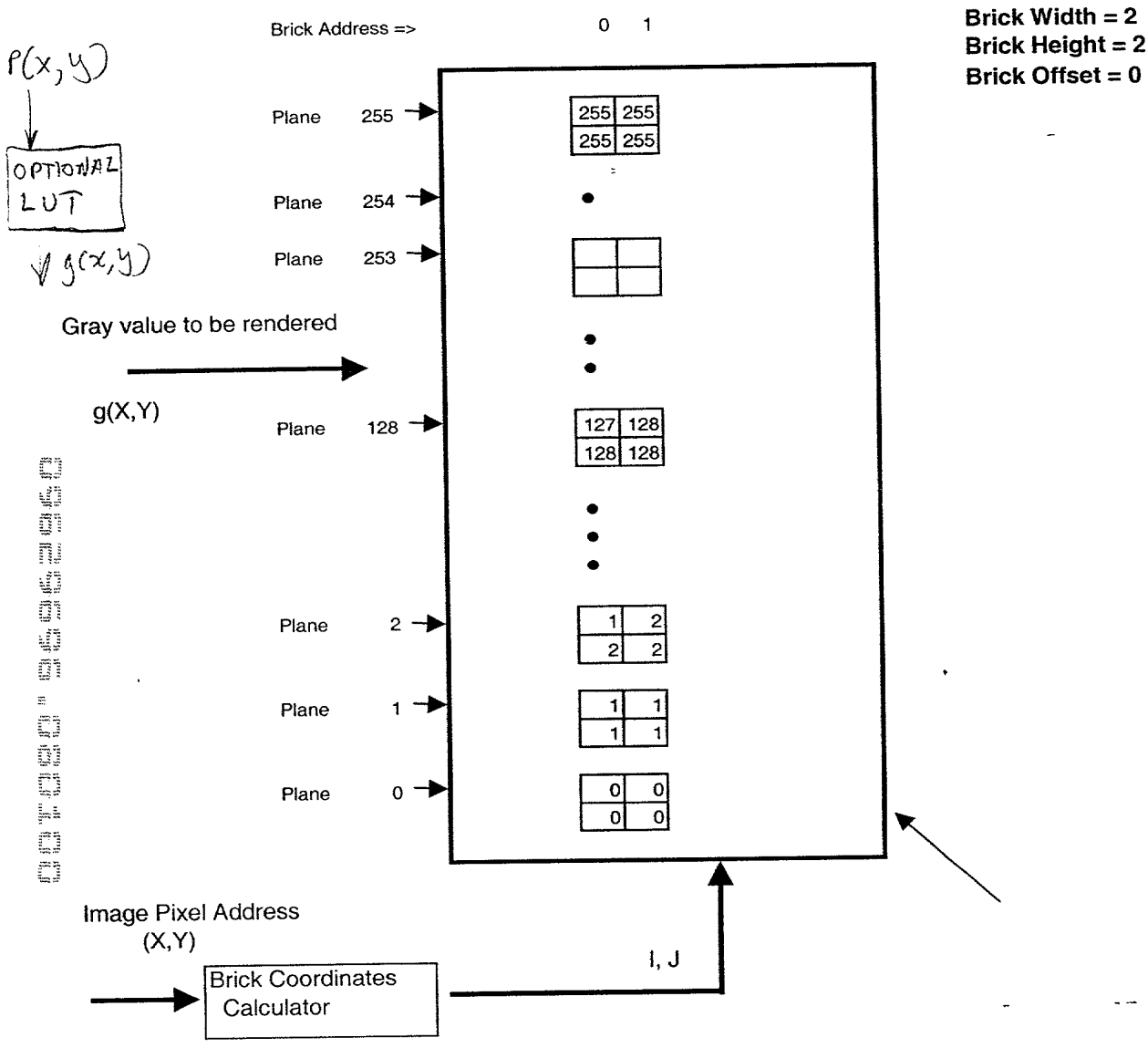


Fig. 4

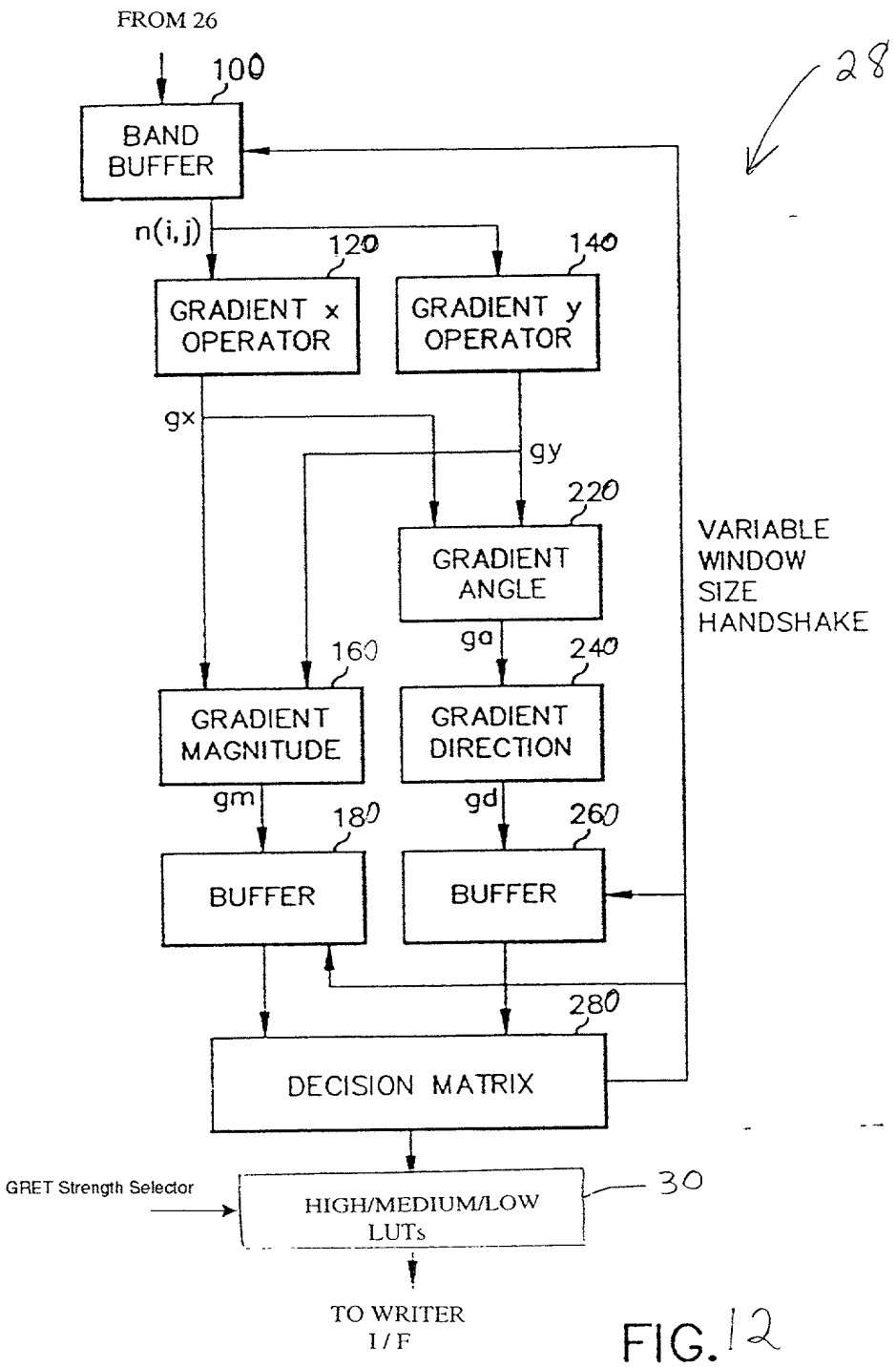

FROM 26
100
BAND BUFFER
28
n(i,j)
120
140
GRADIENT x OPERATOR
GRADIENT y OPERATOR
gx
gy
220
GRADIENT ANGLE
VARIABLE WINDOW SIZE HANDSHAKE
ga
160
240
GRADIENT MAGNITUDE
GRADIENT DIRECTION
gm
gd
180
260
BUFFER
BUFFER
280
DECISION MATRIX
GRET Strength Selector
HIGH/MEDIUM/LOW LUTs
30
TO WRITER I/F

FIG. 12

	Medium	High	Low
0	0	0	0
1	17	33	4
2	34	56	12
3	51	76	23
4	68	95	35
5	85	106	65
6	102	123	81
7	119	139	98
8	136	154	111
9	153	169	135
10	170	184	154
11	187	199	173
12	204	213	193
13	221	227	213
14	238	241	234
15	255	255	255

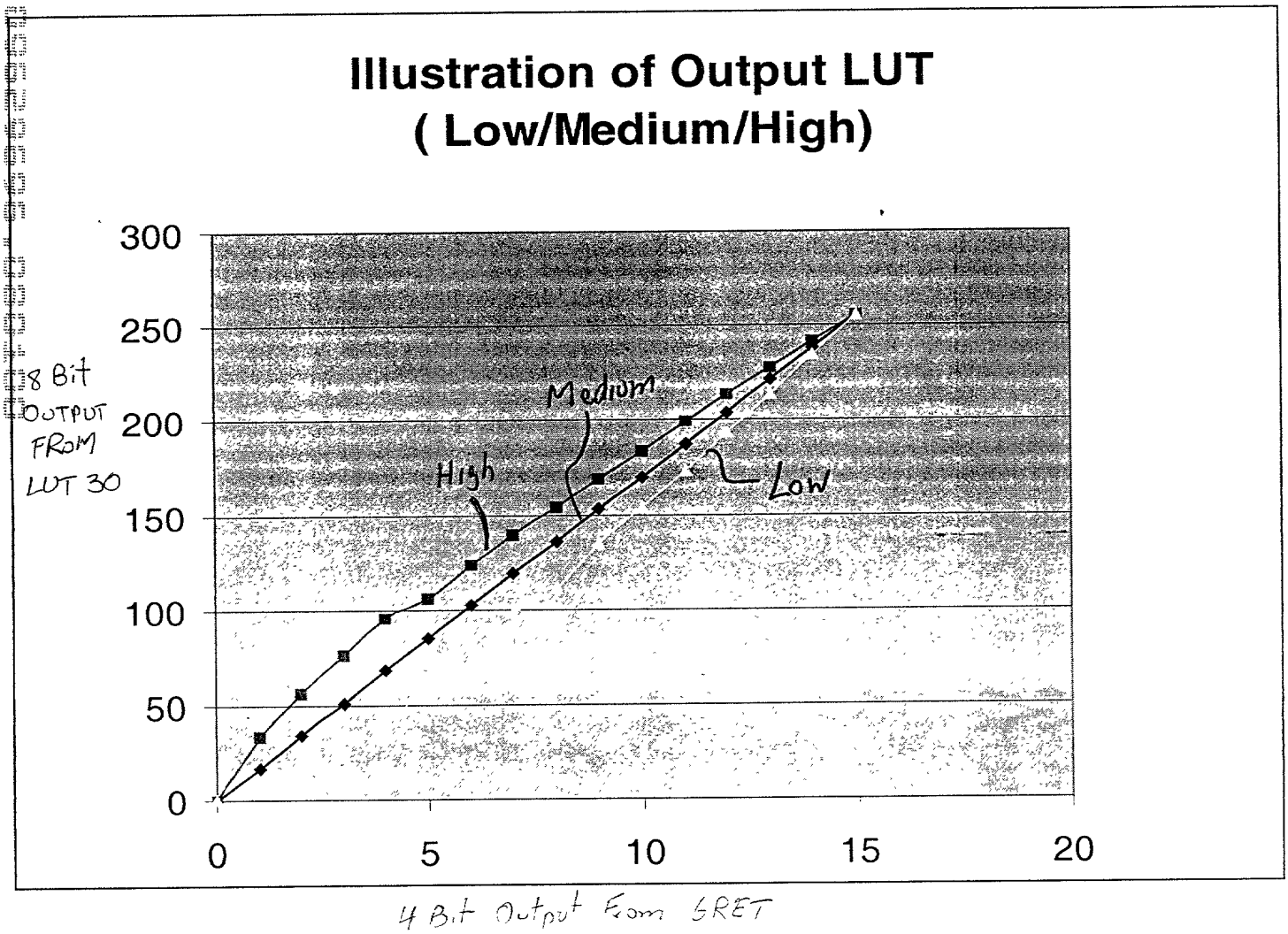


Fig.13

Original Image

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	255	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	255	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	255	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	0
0	0	255	0	0	0	255	255	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	255	0
0	0	255	0	0	0	255	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0
0	0	255	0	0	0	255	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	255	255	255	0	0	0	0	0	0
0	0	255	0	0	255	255	0	0	0	255	255	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0
0	0	255	0	0	255	0	0	0	255	0	0	0	0	0	0	0	0	0	0	255	255	255	0	0	0	0	0	0	0	0	0
0	0	255	0	255	255	0	0	0	255	255	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	0	255	255	0	0	0	0	0	0	255	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	255	255	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	255	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	255	255	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	0
0	0	255	0	255	0	255	0	0	0	255	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	255	0
0	0	255	0	255	0	255	0	255	255	255	0	0	0	0	0	0	0	0	255	255	255	255	0	0	0	0	0	0	0	0	0
0	0	255	0	255	255	255	255	255	0	0	0	0	0	0	255	255	255	255	255	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	0	0	0	0	0	255	255	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	255	255	255	255	255	255	255	255	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 14

GRET Output with LUT: Medium strength

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	255	136	0	0	0	0	0	0	0	0	102	255	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	119	255	119	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	136	255	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	204	204	0	0	0	0	0	0	0	136	255	136	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	255	136	0	0	0	0	0	0	102	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	136	255	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	204	204	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	255	136	0	0	0	0	0	136	255	136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	119	255	119	0	0	0	0	102	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	0	0
0	0	255	0	0	0	136	255	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	136	255	255	0	0
0	0	255	0	0	0	204	204	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	255	0	0	0
0	0	255	0	0	0	255	136	0	0	0	136	255	136	0	0	0	0	0	0	0	0	0	136	255	255	136	0	0	0	0	0
0	0	255	0	0	136	255	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	255	255	255	0	0	0	0	0	0
0	0	255	0	0	204	204	0	0	0	0	255	255	0	0	0	0	0	0	0	0	136	255	255	136	0	0	0	0	0	0	0
0	0	255	0	136	255	136	0	0	136	255	136	0	0	0	0	0	0	0	255	255	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	204	204	0	0	102	255	255	0	0	0	0	0	0	136	255	255	136	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	136	0	0	255	255	0	0	0	0	0	136	204	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	255	255	0	0	0	0	0	255	255	204	136	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	136	255	136	0	0	0	0	255	255	136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	204	204	0	0	0	136	255	255	102	0	0	0	0	0	0	0	0	0	0	119	136	204	255	255	0	0
0	0	255	0	255	0	255	0	0	136	204	255	255	0	0	0	0	0	0	0	0	136	204	255	255	255	204	136	0	0	0	0
0	0	255	0	255	0	255	0	255	255	204	136	0	0	0	0	0	119	136	204	255	255	204	136	119	0	0	0	0	0	0	0
0	0	255	0	255	255	255	255	255	136	0	0	0	0	136	204	255	255	255	204	136	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	0	0	0	0	136	204	255	255	204	136	119	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	255	255	255	255	255	255	255	255	255	204	136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 15

GRET Output with LUT: Low strength

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	255	116	0	0	0	0	0	0	0	0	81	255	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	98	255	98	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	116	255	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	193	193	0	0	0	0	0	0	0	0	116	255	116	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	255	116	0	0	0	0	0	0	0	0	81	255	255	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	116	255	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	193	193	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	255	116	0	0	0	0	0	116	255	116	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	98	255	98	0	0	0	0	81	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	116	255	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	193	193	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	255	116	0	0	0	0	116	255	116	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	98	255	98	0	0	0	0	81	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	0
0	0	255	0	0	116	255	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	116	255	255	0	0
0	0	255	0	0	193	193	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	255	0	0	0
0	0	255	0	0	255	116	0	0	0	116	255	116	0	0	0	0	0	0	0	0	0	0	0	0	116	255	255	116	0	0	0
0	0	255	0	0	116	255	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	255	255	255	0	0	0	0	0	0	0
0	0	255	0	0	193	193	0	0	0	255	255	0	0	0	0	0	0	0	0	116	255	255	116	0	0	0	0	0	0	0	0
0	0	255	0	116	255	116	0	0	116	255	116	0	0	0	0	0	0	0	255	255	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	193	193	0	0	81	255	255	0	0	0	0	0	0	116	255	255	116	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	116	0	0	255	255	0	0	0	0	0	116	193	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	255	255	0	0	0	0	0	255	255	193	116	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	116	255	116	0	0	0	0	255	255	116	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	193	193	0	0	0	116	255	255	81	0	0	0	0	0	0	0	0	0	98	116	193	255	255	0	0	0
0	0	255	0	255	0	255	0	0	116	193	255	255	0	0	0	0	0	0	0	0	116	193	255	255	255	193	116	0	0	0	0
0	0	255	0	255	0	255	0	255	255	193	116	0	0	0	0	0	98	116	193	255	255	193	116	98	0	0	0	0	0	0	0
0	0	255	0	255	255	255	255	255	116	0	0	0	0	116	193	255	255	255	193	116	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	0	0	0	0	116	193	255	255	193	116	98	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	255	255	255	255	255	255	255	255	255	193	116	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 16

GRET Output with LUT: High strength

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	255	154	0	0	0	0	0	0	0	0	123	255	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	139	255	139	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	154	255	0	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	213	213	0	0	0	0	0	0	0	0	154	255	154	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	255	154	0	0	0	0	0	0	123	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	154	255	0	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	213	213	0	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	255	154	0	0	0	0	0	154	255	154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	139	255	139	0	0	0	0	123	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0	255	255	0	0
0	0	255	0	0	0	154	255	0	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	154	255	255	0	0	0
0	0	255	0	0	0	213	213	0	0	0	0	255	255	0	0	0	0	0	0	0	0	0	0	0	255	255	255	0	0	0	0
0	0	255	0	0	0	255	154	0	0	0	154	255	154	0	0	0	0	0	0	0	0	0	0	154	255	255	154	0	0	0	0
0	0	255	0	0	154	255	0	0	0	0	255	255	0	0	0	0	0	0	0	0	255	255	255	0	0	0	0	0	0	0	0
0	0	255	0	0	213	213	0	0	0	255	255	0	0	0	0	0	0	0	0	154	255	255	154	0	0	0	0	0	0	0	0
0	0	255	0	154	255	154	0	0	154	255	154	0	0	0	0	0	0	0	255	255	255	0	0	0	0	0	0	0	0	0	0
0	0	255	0	213	213	0	0	123	255	255	0	0	0	0	0	0	0	154	255	255	154	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	154	0	0	255	255	0	0	0	0	0	154	213	255	255	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	255	255	0	0	0	0	0	255	255	213	154	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	154	255	154	0	0	0	0	255	255	154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	213	213	0	0	0	154	255	255	123	0	0	0	0	0	0	0	0	0	139	154	213	255	255	0	0	0
0	0	255	0	255	0	255	0	0	154	213	255	255	0	0	0	0	0	0	0	154	213	255	255	255	213	154	0	0	0	0	0
0	0	255	0	255	0	255	0	0	255	255	213	154	0	0	0	0	0	139	154	213	255	255	213	154	139	0	0	0	0	0	0
0	0	255	0	255	255	255	255	255	154	0	0	0	0	154	213	255	255	255	213	154	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	255	0	0	0	0	0	0	154	213	255	255	213	154	139	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	255	255	255	255	255	255	255	255	255	213	154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	255	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 17

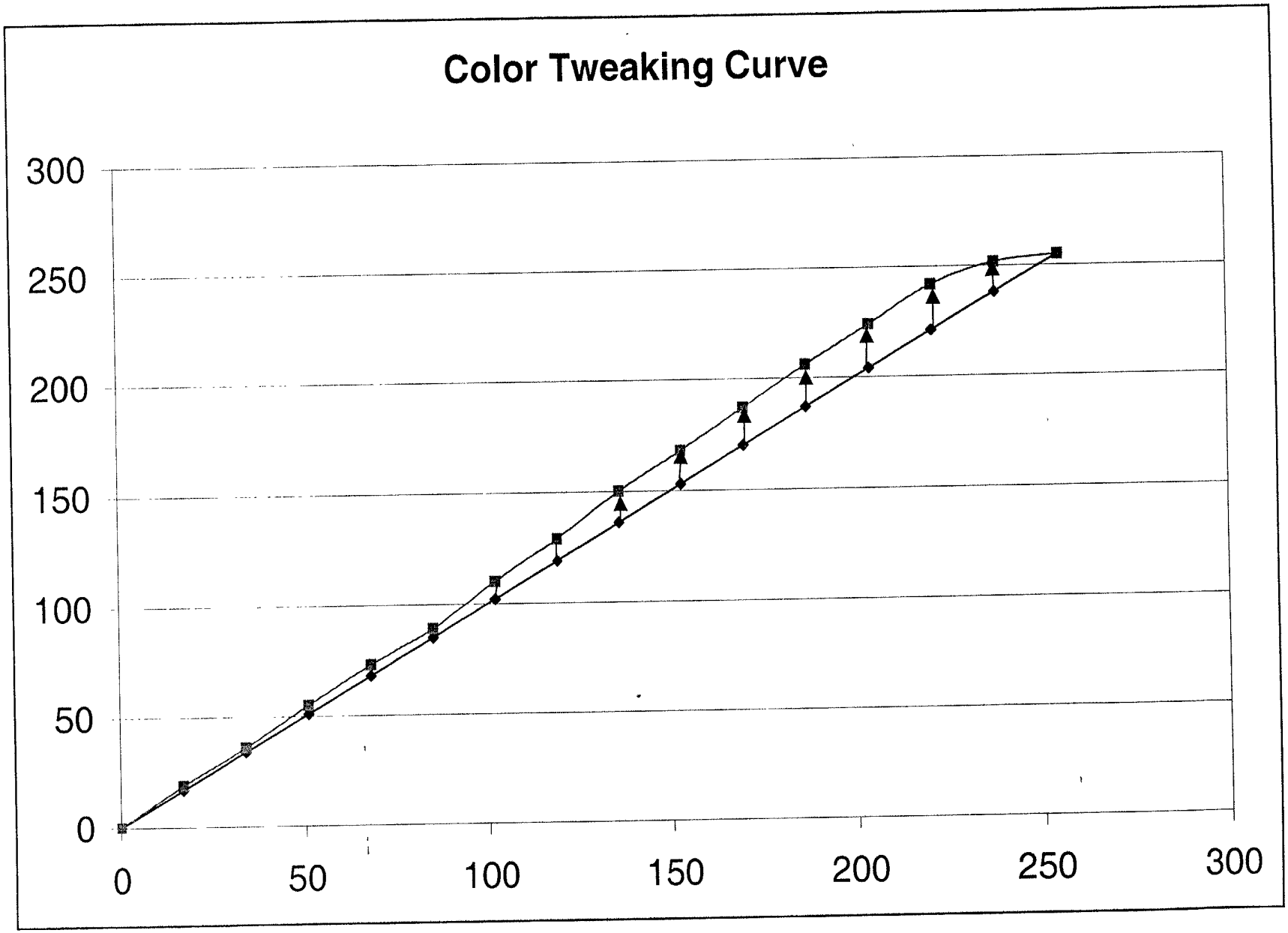

Color Tweaking Curve
300
250
200
150
100
50
0
0
50
100
150
200
250
300
GRAY LEVEL OUT
Gray Level In

Fig. 18

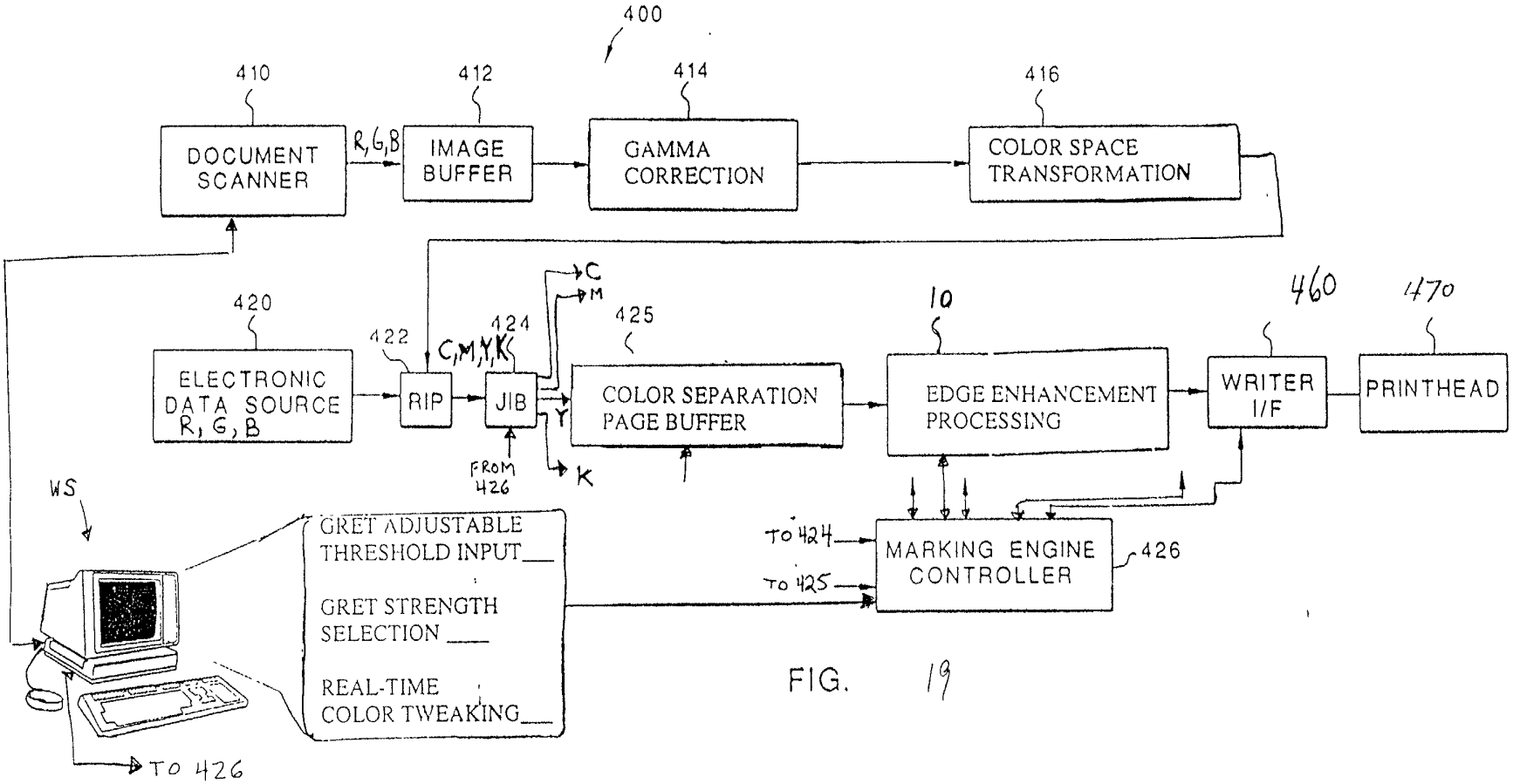

400
410
412
414
416
DOCUMENT SCANNER
R,G,B
IMAGE BUFFER
GAMMA CORRECTION
COLOR SPACE TRANSFORMATION
420
422
C,M,Y,K
424
425
10
460
470
ELECTRONIC DATA SOURCE R,G,B
RIP
JIB
C
M
Y
K
FROM 426
COLOR SEPARATION PAGE BUFFER
EDGE ENHANCEMENT PROCESSING
WRITER I/F
PRINTHEAD
WS
GRET ADJUSTABLE THRESHOLD INPUT___
GRET STRENGTH SELECTION ____
REAL-TIME COLOR TWEAKING___
TO 426
TO 424
TO 425
MARKING ENGINE CONTROLLER
426

FIG. 19

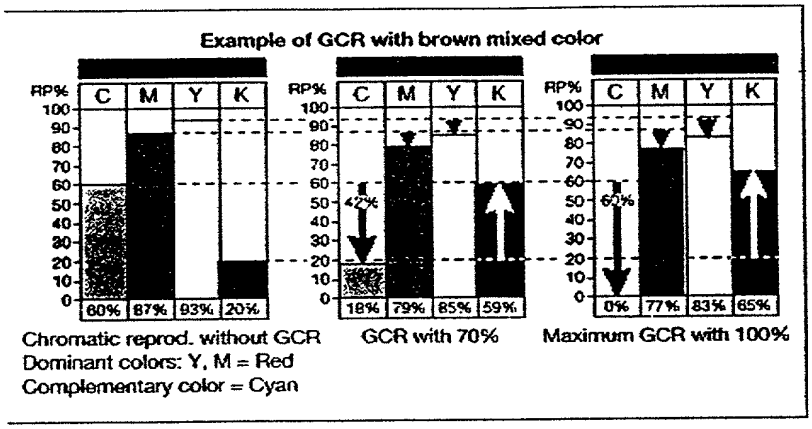


Fig. 20(a)

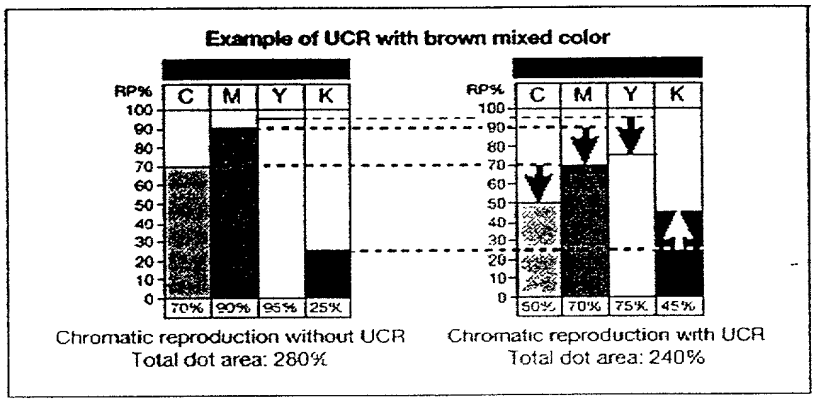


Fig. 20(b)

Illustration of tile structure and brick structure

Screen example: 141 LPI@600 dpi, 45 degree

Step1: **Tile structure**

x	x	x	x	x	x	x
x	x	x	C1	x	x	x
x	x	C1	C1	C1	x	x
x	C1	C1	C1	C1	C1	x
x	C1	C1	C1	C1	C1	x
x	x	C1	C1	C1	x	x
x	x	x	C1	x	x	x
x	x	x	0	x	x	x

Fig. 21-1

Screen Tile Information:

1. **Single cell C1 with one tile**
2. **Screen Angle = 45 degree**
3. **Screen ruling = 141 LPI @ 600dpi**

Step2: **Label pixel sequence in the tile**

0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	0	2	3	4	0	0
0	5	6	7	8	9	0
0	10	11	12	13	14	0
0	0	15	16	17	0	0
0	0	0	18	0	0	0
0	0	0	0	0	0	0

Fig. 21-2

Step3: **Fill up image Plane with tile**

1	10	11	12	13	14	1	10	11	12	13	14	1
3	4	15	16	17	2	3	4	15	16	17	2	3
7	8	9	18	5	6	7	8	9	18	5	6	7
12	13	14	1	10	11	12	13	14	1	10	11	12
16	17	2	3	4	15	16	17	2	3	4	15	16
18	5	6	7	8	9	18	5	6	7	8	9	18
1	10	11	12	13	14	1	10	11	12	13	14	1
3	4	15	16	17	2	3	4	15	16	17	2	3
7	8	9	18	5	6	7	8	9	18	5	6	7
12	13	14	1	10	11	12	13	14	1	10	11	12
16	17	2	3	4	15	16	17	2	3	4	15	16
18	5	6	7	8	9	18	5	6	7	8	9	18
1	10	11	12	13	14	1	10	11	12	13	14	1
3	4	15	16	17	2	3	4	15	16	17	2	3
7	8	9	18	5	6	7	8	9	18	5	6	7
12	13	14	1	10	11	12	13	14	1	10	11	12
16	17	2	3	4	15	16	17	2	3	4	15	16

Fig. 21-3

Step 4: Found repeating rectangle blocks in the image plane

1	10	11	12	13	14	1	10	11	12	13	14	1
3	4	15	16	17	2	3	4	15	16	17	2	3
7	8	9	18	5	6	7	8	9	18	5	6	7
12	13	14	1	10	11	12	13	14	1	10	11	12
16	17	2	3	4	15	16	17	2	3	4	15	16
18	5	6	7	8	9	18	5	6	7	8	9	18
1	10	11	12	13	14	1	10	11	12	13	14	1
3	4	15	16	17	2	3	4	15	16	17	2	3
7	8	9	18	5	6	7	8	9	18	5	6	7
12	13	14	1	10	11	12	13	14	1	10	11	12
16	17	2	3	4	15	16	17	2	3	4	15	16
18	5	6	7	8	9	18	5	6	7	8	9	18
1	10	11	12	13	14	1	10	11	12	13	14	1
3	4	15	16	17	2	3	4	15	16	17	2	3
7	8	9	18	5	6	7	8	9	18	5	6	7
12	13	14	1	10	11	12	13	14	1	10	11	12
16	17	2	3	4	15	16	17	2	3	4	15	16

Fig. 21-4

Step 5: Brick structure formed

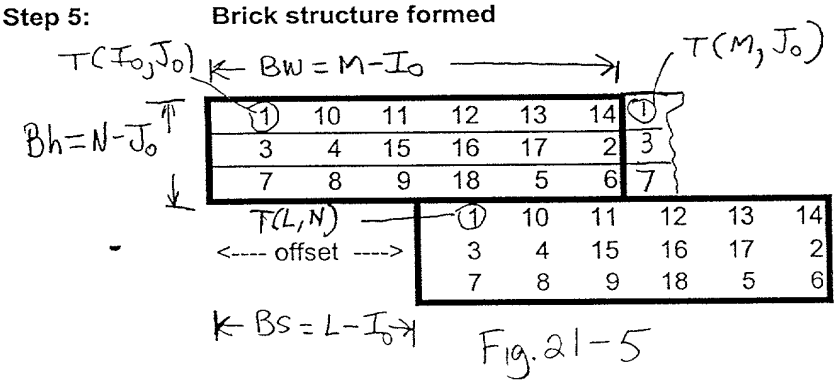


Fig. 21-5

Brick information

1. Brick width = 6 ≈ Bw
2. Brick Height = 3 ≈ Bh
3. Brick Offset = 3 = Bs

Step 6: Converts 3-D LUT Tile structure to 3-D LUT Brick strucuture

Level 0

Level 2

106	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

Level 128

255	231	0	0	0	231
255	231	0	0	0	231
220	99	99	220	100	100

Level 255

255	255	255	255	255	255
255	255	255	255	255	255
255	255	255	255	255	255

Fig. 21-6

Flow chart to construct Brick

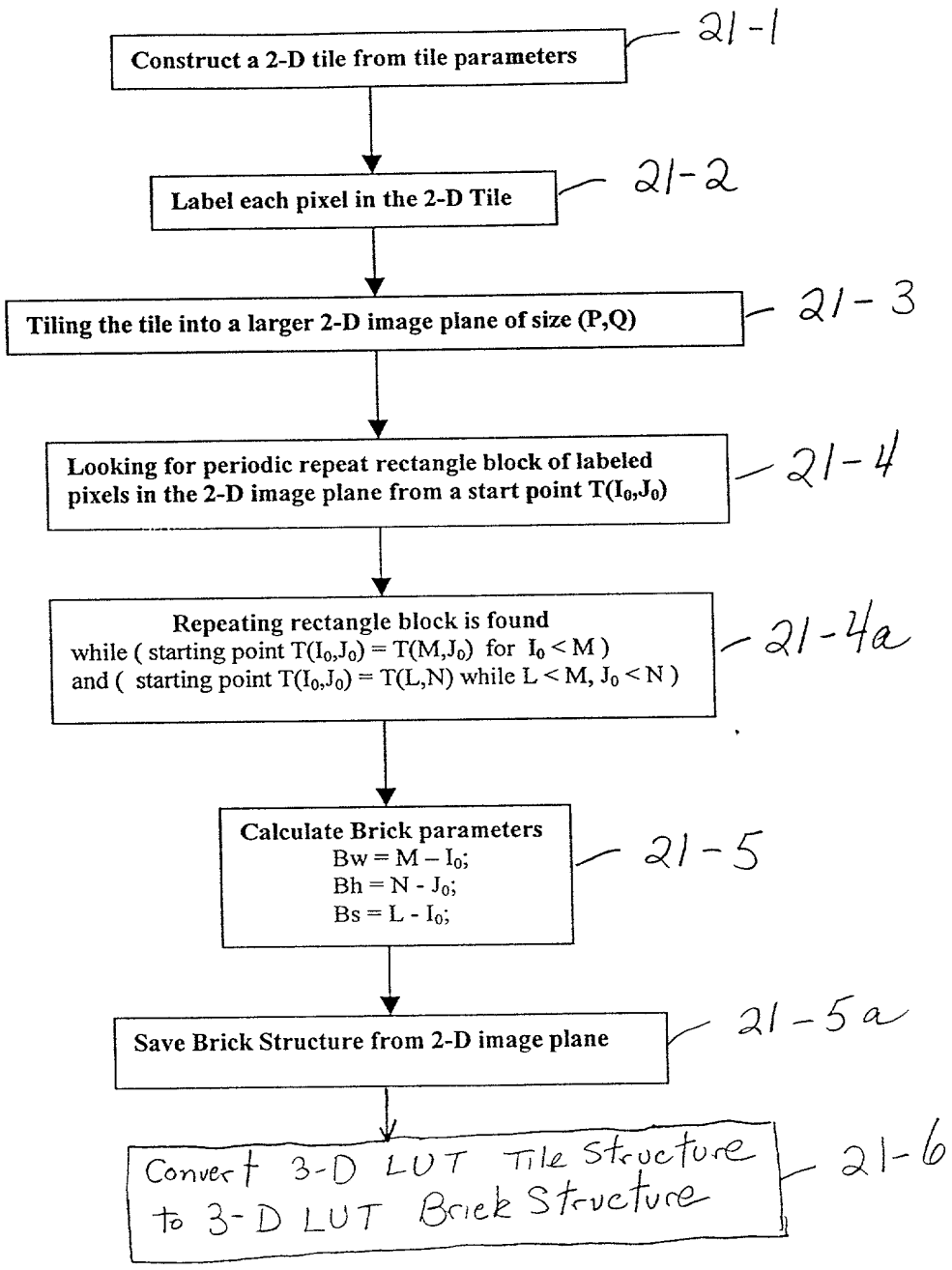
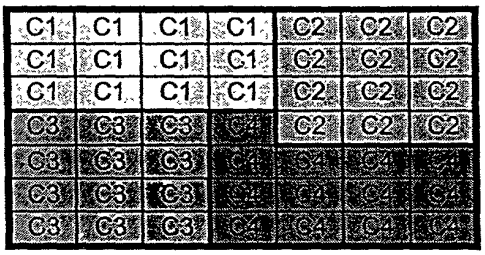


Fig. 22

Screen #2: 171 lpi, 0 degree

Tile structure



Screen Information:

1. Four cells (C1,C2,C3,C4) with one tile
2. Each cell has different shapes
3. Different cell sizes among cells
4. Screen Angle = 0 degree
5. Screen ruling = 171 LPI @ 600dpi
6. Brick width = 7
7. Brick Height = 7
8. Brick Offset = 0

Dot type choices:
(full,partial, mixed, distributed dot type)

Brick structure

S1	E1	S1	E1
S2	E2	S2	E2
S3	E3	S3	E3
S4	E4	S4	E4
S5	E5	S5	E5
S6	E6	S6	E6
S7	E7	S7	E7
S1	E1	S1	E1
S2	E2	S2	E2
S3	E3	S3	E3
S4	E4	S4	E4
S5	E5	S5	E5
S6	E6	S6	E6
S7	E7	S7	E7

S1,S2,..S7 : start of brick pixel

E1,E2,..E7: end of brick pixel

Fig. 23(a)

Screen #2: 171 lpi, 0 degree

Gray level = 2

Dot type: distributed dot type

0	0	0	0	0	0	0
0	31	18	0	7	42	0
0	15	8	0	3	20	0
0	0	0	0	0	0	0
0	8	5	0	2	11	0
0	38	21	0	8	51	0
0	0	0	0	0	0	0

Brick structure

1. Brick width = 7
2. Brick Height = 7
3. Brick Offset = 0

0	0	0	0	0	0	0
0	31	18	0	7	42	0
0	15	8	0	3	20	0
0	0	0	0	0	0	0
0	8	5	0	2	11	0
0	38	21	0	8	51	0
0	0	0	0	0	0	0

Fig. 23(b)

5,930,390

Screen #2: 171 lpi, 0 degree

Gray level = 128

Dot type: distributed dot type

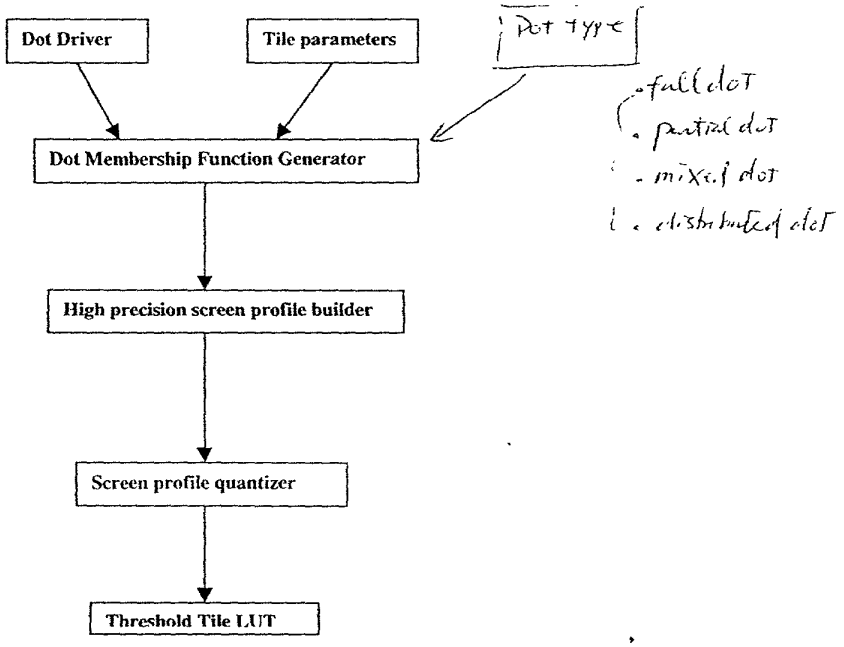
20	164	83	5	83	164	20
164	255	229	132	223	255	164
83	229	163	51	159	233	83
5	132	51	0	51	132	5
83	223	159	51	158	224	83
164	255	233	132	224	255	164
20	164	83	5	83	164	20

Brick structure

1. Brick width = 7
2. Brick Height = 7
3. Brick Offset = 0

Fig. 23(c)

Flow Chart to Construct a Threshold LUT of a Tile



16x16 dot size Driver

256	245	240	224	204	168	136	92	85	129	161	195	219	233	250	255
252	244	232	208	188	160	116	84	73	109	153	181	209	229	241	248
236	228	216	192	176	144	108	80	69	101	137	169	197	213	225	237
217	212	200	180	152	120	100	63	55	93	121	145	177	189	205	221
193	184	172	148	128	58	46	39	35	51	67	125	149	173	185	201
164	156	140	124	66	42	30	22	19	31	43	59	117	141	157	165
132	112	104	96	50	26	14	6	11	15	27	47	97	105	113	133
88	76	72	54	34	18	10	4	3	8	23	37	61	77	81	89
90	82	78	62	38	24	7	2	1	12	17	33	53	70	74	87
134	114	106	98	48	28	16	9	5	13	25	49	95	103	111	131
166	158	142	118	60	44	32	20	21	29	41	65	123	139	155	163
202	186	174	150	126	68	52	36	40	45	57	127	147	171	183	194
222	206	190	178	146	122	94	56	64	99	119	151	179	199	211	218
238	226	214	198	170	138	102	71	79	107	143	175	191	215	227	235
246	242	230	210	182	154	110	75	83	115	159	187	207	231	243	251
254	249	234	220	196	162	130	86	91	135	167	203	223	239	247	253

Fig. 24

Combined Declaration For Patent Application and Power of Attorney	ATTORNEY DOCKET 80097JDL

As below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

EDGE ENHANCEMENT OF GRAY LEVEL IMAGES

The specification of which (check only one item below):

[X] is attached hereto.

[ ] was filed as United States Application Serial No. on and was amended on (if applicable).

[ ] was filed as PCT international application Number on and was amended under PCT Article 19 on (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the U.S. Patent & Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating a least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY (If PCT, indicate PCT)	APPLICATION NUMBER	DATE OF FILING (day month year)	PRIORITY CLAIMED UNDER 35 USC §119			
				YES		NO
				YES		NO
				YES		NO

I hereby claim the benefit under Title 35, United States Code, 119 §(e) of any United States provisional application(s) listed below:

PRIOR PROVISIONAL APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. §119 (e):

PROVISIONAL APPLICATION NUMBER	FILING DATE

I hereby claim the benefit under Title 35, United States Code, §120 of any prior United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior applications(s) in the manner provided by the first paragraph of Title 35, §112, I acknowledge the duty to disclose to the U.S. Patent & Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations §1.56, which became available between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR US APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S FOR BENEFIT UNDER 35USC§120:

U S APPLICATIONS		STATUS (Check one)		
U S APPLICATION NUMBER	U S FILING DATE	PATENTED	PENDING	ABANDONED
PCT APPLICATIONS DESIGNATING THE U S				
PCT APPLICATION NO	PCT FILING DATE	U.S SERIAL NUMBERS ASSIGNED (if any)			

Combined Declaration For Patent Application and Power of Attorney *(Continued)*	ATTORNEY DOCKET 80097JDL

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith ***(List name and registration number)***

James D. Leimbach, Registration No. 34,374
Lawrence P. Kessler, Registration No. 24,637

Send Correspondence to:	**Direct Telephone Calls to:** *(name and telephone number)*
Lawrence P. Kessler NexPress Solutions LLC Patent Department 1447 St. Paul Street Rochester, NY 14653-7001	James D. Leimbach 716/253-0125 FAX: 716/253-5525

2	FULL NAME OF INVENTOR	FAMILY NAME Ng	FIRST GIVEN NAME Yee	SECOND GIVEN NAME S.
0	RESIDENCE & CITIZENSHIP	CITY Fairport	STATE OR FOREIGN COUNTRY NY 14459	COUNTRY OF CITIZENSHIP USA
1	BUSINESS ADDRESS	BUSINESS ADDRESS NexPress Solutions LLC	CITY 1447 St. Paul Street, Rochester	STATE & ZIP CODE (COUNTRY) New York 14653-7001
2	FULL NAME OF INVENTOR	FAMILY NAME Tai	FIRST GIVEN NAME Hwai-Tzuu	SECOND GIVEN NAME
0	RESIDENCE & CITIZENSHIP	CITY Rochester	STATE OR FOREIGN COUNTRY NY 14625	COUNTRY OF CITIZENSHIP USA
2	BUSINESS ADDRESS	BUSINESS ADDRESS NexPress Solutions LLC	CITY 1447 St. Paul Street, Rochester	STATE & ZIP CODE (COUNTRY) New York 14653-7001 USA
2	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
0	RESIDENCE & CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
3	BUSINESS ADDRESS	BUSINESS ADDRESS	CITY	STATE & ZIP CODE (COUNTRY)
2	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
0	RESIDENCE & CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
4	BUSINESS ADDRESS	BUSINESS ADDRESS	CITY	STATE & ZIP CODE (COUNTRY)
2	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
0	RESIDENCE & CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
5	BUSINESS ADDRESS	BUSINESS ADDRESS	CITY	STATE & ZIP CODE (COUNTRY)
2	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
0	RESIDENCE & CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
6	BUSINESS ADDRESS	BUSINESS ADDRESS	CITY	STATE & ZIP CODE (COUNTRY)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

SIGNATURE OF INVENTOR 201	SIGNATURE OF INVENTOR 202	SIGNATURE OF INVENTOR 203
Yee S. Ng	Hwai-Tzuu Tai	
DATE July 27, 2000	DATE July 27, 2000	DATE
SIGNATURE OF INVENTOR 204	**SIGNATURE OF INVENTOR 205**	**SIGNATURE OF INVENTOR 206**
DATE	DATE	DATE